

Historic Movable Bridges of New Hampshire

Prepared by
Richard M. Casella
Historic Documentation Company, Inc.
Portsmouth, Rhode Island
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New Hampshire Department of Transportation
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*Chart of coast of New Hampshire, near
Portsmouth and the Isles of Shoals. ca. 1777.*

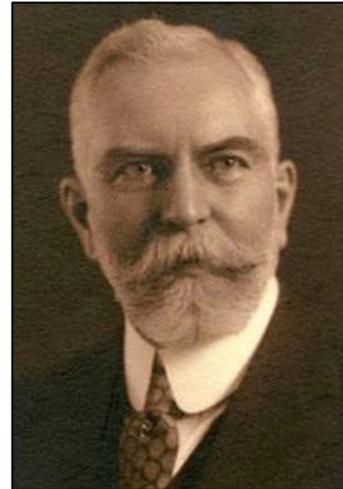
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1. INTRODUCTION

A movable bridge, in the context of New Hampshire's transportation history, is a highway or railroad bridge that can be drawn up, pulled back or swung aside "so as to open a clear passage, or to afford an increased headway, for ships or boats in a navigable channel."¹ The ancient term, *draw bridge*, which conjures the image of a defensive structure of heavy timbers spanning a moat around a medieval castle and drawn up by heavy chains to form a door, remains in common use for movable bridges of all types. Federal laws enacted in the 19th century up to the present US Coast Guard regulations use the term drawbridge.

Engineers since the beginning of the 20th century have preferred the term movable bridge, cemented into their lexicon by the treatise *Movable Bridges* written by Otis E. Hovey in 1926. Movable bridges of the three major types, swing, lift and bascule, as well as the rare traversing type, have been built over New Hampshire's navigable waterways since the mid-17th century.

Despite having the shortest ocean coastline of any state – 18.57 miles or 13 miles depending who you ask – New Hampshire possesses two great estuaries that total 235 miles of "estuarine shoreline."² Of the seventeen historic movable bridges individually documented in this report, fifteen were built within the Piscataqua River and Great Bay estuary, a watershed covering 730 square miles and touching forty-six New Hampshire towns. Two bridges were built over the inlet to the Hampton River Estuary, a smaller predominantly salt-marsh estuary behind barrier beaches covering about 1152 acres.³ Eleven of the seventeen bridges carried highways, three carried both highway and railroad tracks, two carried highway and street railway tracks and one carried just railroad tracks. Two new monumental movable bridges, both vertical lift spans spanning the Piscataqua River in Portsmouth, have been recently completed, replacing spans of the same type. Memorial Bridge – 2013, replaced Memorial Bridge – 1923; Sarah Mildred Long Bridge – 2018, replaced Sarah Mildred Long Bridge – 1940. When these bridges reach fifty years of age they may be added to the roster of the state's historic bridges, as representatives of their class of technically sophisticated structures and the state's largest transportation project undertakings.



Otis Ellis Hovey (1864-1941) graduated Dartmouth College with the degree of civil engineer in 1889 and became the world's foremost authority on movable bridges. See note 15 for more on Hovey. Courtesy Dartmouth College Engineering Magazine.

Bridges equipped with a movable channel span are typically far more expensive than a similar bridge with fixed channel span. This is due to their greater design, manufacturing and construction costs, the high maintenance of their mechanical parts and their electrical parts if so equipped, and the cost of the labor for their operation. Building a movable bridge is therefore naturally resisted by those seeking to span a navigable channel with no interest in maintaining its navigability. As a result, laws to maintain navigable waterways in the interest of national commerce were established early in the history of the country. Much of the law is rooted in the ancient principles of the public trust doctrine, which treats access to the sea, air and running water as a right common to all. Clause 33 of the Magna Carta prohibited impediments to free navigation on England's rivers and the judicial precedents that followed came to America with its settlement to form the basis of our legal system known as English common law.

The following section, *The Right to a Navigable Waterway*, addresses American and New Hampshire navigation law as it applies to the subject of movable bridges. The characteristics of the various types of movable bridges that have been built in New Hampshire is discussed in Section 3. A short illustrated history of each of the state's seventeen known historic movable bridges is presented in Section 4.

2. RIGHT TO A NAVIGABLE WATERWAY

In 1911 the New Hampshire Legislature defined the state's navigable streams or waters as "those which are used, or are susceptible of being used in their ordinary condition, as highways for commerce, over which trade or travel are or may be conducted in the present customary modes of trade or travel on water."⁴ This definition retains its legal authority today.

As previously noted, lawmakers have long viewed traffic by water as having superior rights to traffic by land. It is argued that since the water highway was in a natural state unhindered by any bridges crossing it, its users have a perpetual right to free and unhindered navigation.⁵ These early waterway rights have been compared to property rights that cannot be taken away or infringed upon regardless of the magnitude of the interests of the land traffic. This reasoning dates to the time before railroads when the vast majority of commerce traveled on water and but a small fraction moved on land.

In the United States during the first decades of the 19th century, the development of steamboat commerce on inland rivers of the United States resulted in disputes over state versus federal jurisdiction over navigation on waters within state boundaries. In 1824 the US Supreme Court ruled in *Gibbons vs. Ogden*, that regulation of navigation by steamboat operators and others for purposes of conducting interstate commerce was a power reserved to and exercised by the Congress under the Commerce Clause of the Constitution.⁶ Congress continues to hold exclusive power over interstate commerce, negating state laws that interfere with that power. Passage of the first Rivers and Harbors Act, also in 1824, marked the beginning of many acts that authorized and funded the Army Engineers to make surveys and improve the country's waterways for navigation.

New Hampshire's recognition of navigation rights significantly predates the nation as a whole. In 1731 the town of Portsmouth gave permission to individuals to build a toll bridge over the inlet to Puddle Dock cove providing it was equipped with a hoist or draw for vessels to pass through. In 1747 the General Court of New Hampshire granted petitioners the right to bridge Squamscott River from New Market to Stratham with the condition it was equipped with a draw 28 feet wide but objections by shipping interests and lack of funding stalled construction until 1773. In 1792 the Legislature passed *An Act to prevent obstructions and impediments to Navigation in the River Piscataqua and Harbor of Portsmouth*; the law prohibited the dumping of "ballast and other annoyances from Vessels and boats, as well as from the Shore or bank...that tend to fill up or lessen the channel...to the detriment and obstruction of Navigation."⁷

The monumental Piscataqua [River] Bridge built 1794 from Durham to Newington was required by law to maintain navigation through two channels, one fitted with a draw for tall ships and the other with an arched truss that provided sixteen feet of clearance at high tide for barges, scows and small local merchant vessels known as gundalows. Subsequent laws enabling the construction of bridges over navigable waterways in the state followed these precedents and included wording in some form that required a draw span that allowed vessels to pass without hindrance.

The rampant expansion of railroads across the country during the second half of the 19th century met with the need to span large navigable rivers between states that were subject to federal jurisdiction. In some cases bridges and their approaches could be elevated sufficiently to allow river traffic to pass beneath, but in other instances a movable bridge was the only practical solution. During this period railroad engineers led the way in the development of increasingly longer and heavier draw spans of varying structural and mechanical design. Several examples of early railroad draw spans were built in New Hampshire.

Beginning in 1870, Congress began an ongoing program of federal funding for river and harbor navigation improvements by the Army Corps of Engineers (Army Corps). Lawmakers feared the railroads were securing a monopoly on commercial transportation and many of the River and Harbor Acts during the 1880s were meant to increase the competitiveness of waterborne transport by subsidizing channel dredging and removal of impediments to navigation.

By 1890, the Secretary of War was empowered to remove bridges, dams, causeways or other structures not authorized by law that obstructed navigation. The Rivers and Harbors Act of 1899 made all tidal waters

and their tributaries to the head of tide "Navigable Waters of the United States" and subject to permit jurisdiction by the Army Corps.⁸

The General Bridge Act of 1906 specified rules under which bridges may be constructed over navigable waterways, many remaining in effect today: plans must be submitted and approved by the Army Corps; no bridge shall unreasonably obstruct the free navigation of the waters over which it is constructed due to insufficient height, width of span, or insufficiency of the draw opening or span; and, draws must be opened promptly for the passage of water craft upon reasonable signal.

Shortly after passage of the Bridge Act the question of what constitutes prompt opening of the draw was tested when a boat was delayed passage for ten minutes until a mail train that was fast approaching was given the right-of-way and allowed to pass first. The Army Corps ruled that when it is necessary to delay either a train or a boat, the boat must be given preference. The decision prompted a debate in which another ancient doctrine was invoked, that rights and privileges should be tempered to effect the *greatest good to the greatest number*. That an "old scow loaded, perhaps, with manure or some similar cheap bulk freight" could be given priority of passage and delay a heavy freight or "passenger train carrying ten thousand passengers," was viewed by engineers favoring the railroad's priorities as "a gross absurdity to put the case very mildly."⁹

The counter argument, offered by a civil engineer with the Army Corps, was that boats compared to trains or other land vehicles are under much less control in stopping and holding:

Every boat has to be kept in motion to be under control of its pilot. When he stops and floats his boat is the sport of wind and current. As a boat approaches a draw, the pilot's task becomes then the solution of delicate problems of current, wind, momentum, steering power and velocity through the water. All pilots know that they are perpetually combining forces into a resultant that means the wrecking or the safety of the boat.¹⁰

The law as written in 1906 held fast and gradually boat owners and drawbridge owners alike modified their practices and equipment to reduce their exposure to damages and expensive litigation. Commercial vessels such as river tugs and barges were designed with lower heights to clear channel openings under fixed spans and avoid using draw openings wherever possible. Recreational boats today are designed with heights under 65' to clear bridges on the Atlantic Intracoastal Waterway. Drawbridge owners installed higher speed operating equipment or replaced slow draw spans entirely to limit delays to bridge traffic.

The Bridge Act of 1946 codified the fundamentals of the 1906 Bridge Act with other minor amendments and constitutes the backbone of today's drawbridge rules embodied under *Title 33 Navigation and Navigable Waters* of the US Code of Federal Regulations. In 1966 the functions of the Bridge Act were transferred to the Secretary of Transportation to be administered by the Coast Guard. Currently under Title 33 there are three specific regulations governing the operation of New Hampshire's last remaining drawbridges spanning Piscataqua River, Hampton River and Little Harbor.¹¹ The Coast Guard continues to address each request to alter, replace or build new bridges over navigable waterways on a case-by-case basis. The Coast Guard's Bridge Permit Application¹² requires extensive technical information and reporting on all aspects of the project's purpose and need, design, and effects on navigation and the environment. For example, twenty-two potential impacts to the environment must be evaluated and documented, including actions to address environmental justice, endangered species and effects to historic resources.

3.0 MOVABLE BRIDGE TYPES

3.1 Definitions.

Over time there has been some disagreement among engineers regarding the classification of movable bridge types, in particular the bascule. Merriman Mansfield and Henry Jacoby in their highly regarded 1897 four volume *Text-book on Roofs and Bridges* stated that

Modern draw bridges may be classified as swing bridges, rolling bridges, and lift bridges, the first being the most common type. A swing bridge is supported upon a pier at the middle, and when closed the ends rest upon abutments. When open each arm is a cantilever. The old form of swing bridge had a tower over the center pier, from which inclined chains extended to the ends. Rolling draw bridges are those which have wheels under the land portions, and which can be pushed out to span the stream. A rolling bridge is pulled back by the rope and drum method. Lift bridges are of various kinds. The simplest is a common truss which is raised vertically to the desired height, both ends rising in guides arranged on towers. The hinged lift bridge moves in a vertical plane around hinges at one end, like the ancient draw over the castle moat. Pulled up or let down by a chain, it embodied the general ideas of the hinged lift structure shown in Fig. 41. A lift bridge usually has a counterweight to assist the motion.¹³

In 1907 another renowned bridge engineer, Charles C. Schneider (1843-1916) proposed classifying all bridges that turn about a horizontal axis or roll back on a circular segment as bascule bridges.¹⁴ This included the "hinged lift" type so-named by Mansfield & Jacoby. Schneider had no argument regarding swing bridges – those which turn about a vertical axis – but lift bridges he said, lift vertically in a plane.

In 1926, when Otis Hovey, the foremost authority and engineer of movable bridges published his seminal two-volume text on the subject, *Movable Bridges*, he clarified the definition of the types:¹⁵

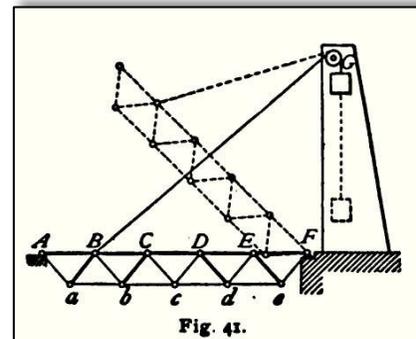
Swing bridges consist of a superstructure arranged to turn about the vertical axis of a pivot anchored to the center pier. In ordinary cases the pivot is at the center of a span of two equal arms, which balance each other when the bridge is open, thus providing two equal openings for navigation. It is sometimes necessary to place the pivot near one end. The shorter arm must then be counterweighted to balance the longer arm when the bridge is open.

Bascule bridges are, strictly speaking, those in which one end rises as the other falls, but the term is commonly applied to any type moving about a horizontal axis, either fixed or moving, as well as to those that roll back on a circular segment [Schneider's thinking has prevailed]. They may consist of a single leaf spanning the channel or of two symmetrical leaves meeting at the center.

Lift bridges move vertically and consist of simple spans resting on piers when closed. In most cases the weight of the lifting span is counterweighted by means of ropes, or chains, attached to the ends of the span and the counterweights, which pass up and over sheaves on top of towers at the ends of the bridge.

Retractable, or traversing, bridges move horizontally and when closed form simple spans across the channels. Some telescope inside of the adjoining spans; others recede above the approaches, the rear end being tilted upward and the free end downward. In some cases the approach span is first moved aside, transversely, to permit the draw span to recede in its place.

Transporter bridges and pontoon bridges are the two additional types of movable bridges identified by Hovey, neither of which were built in New Hampshire.



Mansfield & Jacoby classified the bridge above as a hinged-lift; other later classified the type as a hinged bascule. A cable attached near the free end passes over a pulley on the vertical tower and supports a counterweight. This unbalanced system made it hard to start the bridge and to slow its speed when nearly raised and the type fell out of favor. Numerous bridges of this type built in New Hampshire in the 18th and 19th centuries. Although *bascule* means "a balance" in French, most engineers have conceded to the later typology so *hinged bascule* is used for the type in this report.

3.1 Bascule

Bascule is a French word used to describe mechanical devices that pivot about a point so that when one end or part rises, the other end or part falls. A true bascule bridge consists of a bridge superstructure with a counterweight at one end and a pivot point that enables the superstructure to be raised, rotating in a vertical plane like a see-saw, while the counterweight falls. When two bascule bridges extend across a channel and meet in the middle to form a continuous roadway, the structure is called a double-leaf bascule bridge. A leaf is the portion of the bridge that extends over the channel and carries the roadway. The vast majority of modern bascule bridges, those dating to about 1890 through the twentieth century, are of two basic types, the trunnion type and the rolling-lift type.

The term *trunnion* has evolved in engineering to mean a pin or pivot on which something pivots. Trunnions are the projecting pins on the side of a cannon that sit in the cheeks of the carriage and allow the barrel to be pivoted up and down. The trunnion bascule is also called a simple-lever bascule because in operation it rotates about a stationary pin or pivot-point like a lever and fulcrum. The trunnion bridge consists of a girder or truss superstructure with a heavy counterweight at one end, supported at its balance point by a trunnion anchored to the pier, or abutment, at the edge of the channel. The trunnion bascule bridge is the older of the two types, with primitive versions dating at least as far back as medieval times when counterweighted drawbridges were erected over moats to protect a castle entrance. The monumental Tower Bridge, built over the Thames in London from 1885 to 1894, is a trunnion bascule and according to bridge engineer J. A. L. Waddell, "the modern era of bascule building may properly be said to have commenced with the construction of the Tower Bridge of London in 1894." ¹⁶

The rolling-lift bascule does not have a stationary pivot point but rather one that moves, horizontally, away from the water's edge as the bridge opens. Rather than pivoting on a trunnion, the balance point of the rolling-lift bascule is fitted with a large semi-circular rocker, called a quadrant or "heel," which rolls on a horizontal track, laid perpendicular to the channel, on top of a supporting pier or abutment. The first modern rolling-lift bascule was invented in Chicago in 1893 by William Scherzer and erected in that city in 1895. The rolling bascule is not a type that has been built in New Hampshire.

3.2 Swing

At least five bridges with swing-spans representing three different sub types have been built in New Hampshire. Swing spans revolve about a vertical axis. The type originated in ancient times, advanced in design during the Renaissance, and flourished from the late nineteenth to the mid-twentieth centuries. There are indications that the Egyptians constructed some form of swing bridge as early as 1355 BC, and the Romans are known to have also experimented with the type.

About 1500, Leonardo da Vinci made a sketch of an unequal-armed, or bob-tailed, pivot-bearing swing bridge which was swung by means of hand winches. The oldest identified draw span in the state, Puddle Dock Bridge built 1731, is believed to have been a skewed bob-tailed swing of wood construction. The bob-tailed swing was suited to narrow openings and required some form of counterweight on the shorter arm to balance it over the pivot. The swing was operated by ropes attached to the end of the short arm, drawn from shore by block and tackle or a winch.

By the early nineteenth century center-bearing swing spans with symmetrical arms balanced on the pivot were in use and the type ultimately dominated long span railroad draw bridges in late nineteenth and early twentieth-century. The center-bearing type rests on a single pivot point and is prevented from tilting by four or more balance wheels which roll on a circular track along the outer edge of the support pier. The wheels are not designed to carry any load except that incurred by unbalanced conditions such as wind load. Two center bearing swing railroad bridges were built in New Hampshire in the early 20th century to replace earlier swing bridges of the rim-bearing cable-stayed type (Portsmouth & Dover Railroad, Dover Point Bridge) and shear pole type (Portsmouth & Concord Railroad, Great Bay Bridge).

Two less common types of swing bridges were developed and used in the 19th century in New Hampshire: the rim-bearing swing and the shear pole swing.

The rim-bearing swing rests on a circular girder call a drum, generally equal in diameter to the width of the bridge, which is supported along its bottom rim by continuous series of wheels. The wheels roll along a steel rail mounted along the outer edge of the support pier. Rim-bearing bridges were beset with problems and in the 1870s American engineers returned to the center-bearing type.¹⁷

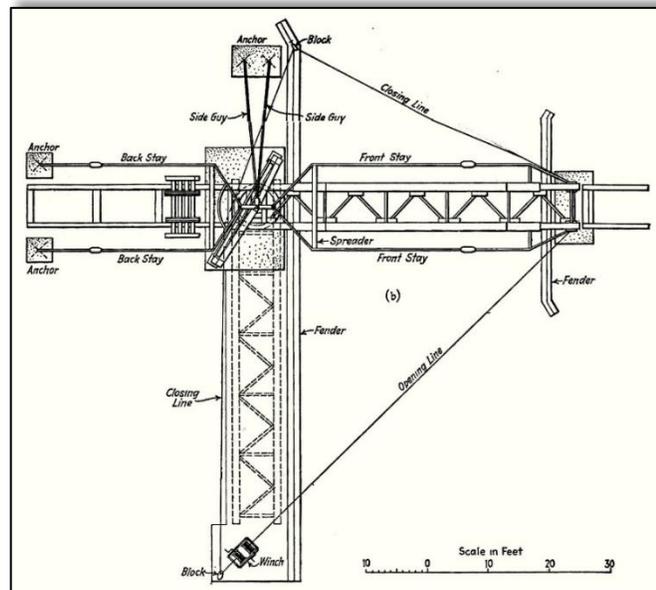
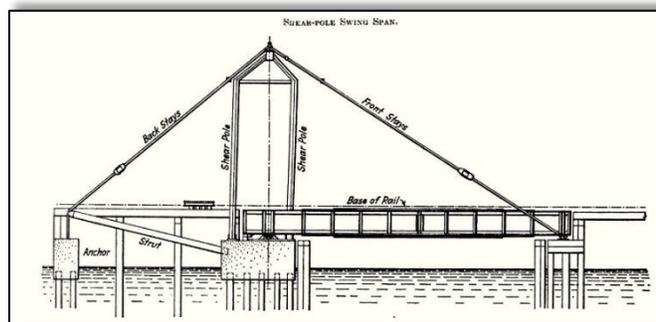
The shear-pole swing is an unusual and uncommon type. According to Terry L. Koglin in *Movable Bridge Engineering*, 2003:

A shear pole swing bridge is pivoted on one end, approximating a bobtail-type or asymmetrical swing span. The free end of the shear pole swing span is supported by tension rods or cables reaching down from an overhead structure. This structure usually consists of derrick-type posts, forming an A-frame around and above the pivot end of the bridge. This A-frame is guyed appropriately by cables stretching to the rear and side of the A-frame. The operation of the bridge may be by means of a cable drum arrangement that pulls the bridge open and closed, but some of these bridges had rack and pinion machinery drives, similar to conventional swing bridges. Typically, the bridge was a simple span, with the long end simply sliding into the closed position onto supporting masonry plates or strike plates. In some cases the railroad-type had simple open joints in the rails at the ends of the swing span. There were once many examples of this type of bridge in use.¹⁸

The shear pole swing has been generally used for narrow highways, single-track railways and short spans with clear openings up to 50 feet. The major disadvantage of the shear pole swing is its unbalanced condition when swinging and the resultant complex loading on the supporting shear leg structure. The need for sound anchorage of the guys and braces limits the span of such structures when adequate foundations are difficult. The advantages of the type have been low first cost and fast operation compared to other movable span types.



Cable stayed wood truss swing bridge of the Puget Sound Electric Railway, 200' span, ca. 1890. Compare to Portsmouth & Dover Railroad, Dover Point Bridge, Section 4.8.



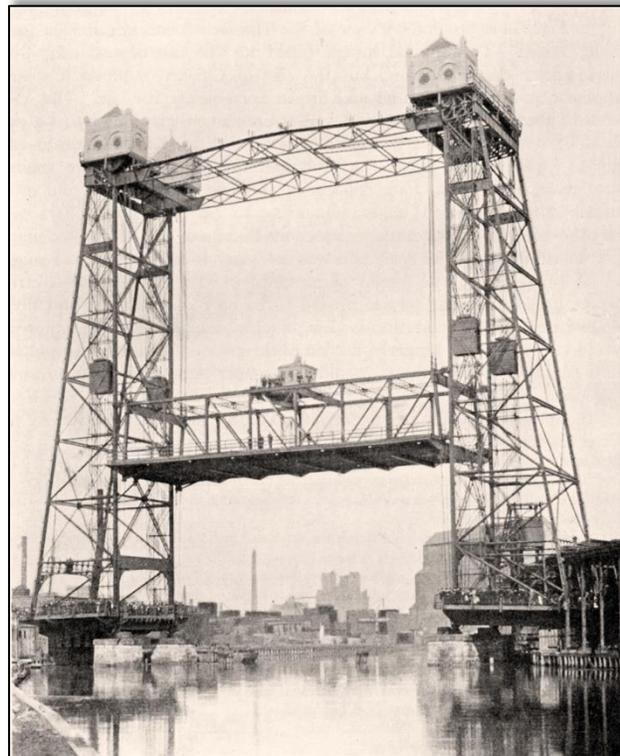
Shear pole swing of the type used by the Eastern Railroad, see Section 4.6, and the Portsmouth & Concord Railroad, see Section 4.7 (Hovey 1926).

Swing spans in general need to be lifted clear of the abutments when opening and set back down when closing. Many different mechanisms to accomplish this have been devised, with the “wedge” type end lift ultimately prevailing due to their simplicity and reliability. The moving end of the shear pole swing was lifted by its hoist cables and did not require mechanical end lifts. Ropes and a block and tackle or winch were first used to open and close swing spans, followed by a rack and pinion or other system of reduction gears operated manually from the swing span. Machinery powered by steam engines, then electric and gasoline powered motors were used to open large spans or speed up the process.

3.3 Vertical Lift

A very few small short-span vertical lift roadway bridges were built in Europe during the 19th century. A vertical lift railroad bridge of 30' span and rise of 10' was built over the Surrey Canal in England about 1857. In the United States, the first vertical lift bridge designs were patented by Squire Whipple in 1872 and built soon after to span the Erie Canal, but these were also small insignificant structures.¹⁹

In 1893 and 1894 John A.L. Waddell designed, patented and oversaw the construction of what is considered the first large modern vertical lift bridge in the world. Known as the Halsted Street Lift Bridge, the 130' span rose like an elevator to a height of 155' on two high steel towers that straddled the Chicago River.²⁰ Waddell's patent blocked others from building vertical lift bridges and it was not until 1907 when John L. Harrington joined Waddell in partnership that the pair revised the earlier design and found customers willing to build the type. In that year they designed and built a 234' span over the Mississippi for the Iowa Central Railway Company. A steady business for "Waddell lift bridges" soon developed and by 1916 over thirty of the firm's designs were built.²¹



Waddell's Halstead Street Lift Bridge, Chicago, 1894.

When Waddell's patent expired in 1910, others began to enter the field. Harrington proved inventive in his own right and patented lift bridge designs in 1910, 1912, and 1913, four with Waddell and two individually. In 1914 Harrington quit Waddell and formed a partnership with Ernest E. Howard and Louis R. Ash and soon these men rose to prominence as leaders in movable bridge design, including vertical-lifts.

In 1920 Waddell was awarded the contract for the monumental Piscataqua River Bridge to carry US Route 1 into Maine. The first of its type in New Hampshire and New England, it was instantly famous and stood as the dominant landmark of the region for 90 years before being replaced in 2013 with another highly innovative bridge representing the first of its type in the U.S.

By 1924 approximately twenty-five vertical-lift highway and eighteen railway bridges based on the original Waddell design had been built in the United States, with nearly all attributable to either Waddell or the firm of Harrington, Howard and Ash.²² The vertical-lift bridge possessed distinct advantages over other types of movable bridges in some applications. For long spans they were more economical than bascules or swing bridges and could be built up to the limits of simple-span trusses. Being simply supported spans, they were easier to design than the swing or bascule types.

In comparison to swing bridges, vertical-lifts possessed additional advantages. They open and close faster than a swing bridge and do not obstruct the channel with a center pier; future additional bridges can be built closely alongside; and the shoreline to either side is available for water commerce – not the case with swing bridges. Vertical lift bridges can easily be made as wide as necessary, whereas wide swing bridges are usually infeasible or uneconomical, and this led to their wide adoption as replacement structures. When one-track railroad or narrow highway swing bridges could no longer handle the increasing traffic, the wide right-of-way they possessed conveniently provided the necessary real estate for a new two-track railway or four-lane highway vertical-lift bridge. Dozens of swing bridges were replaced with wider lift bridges during the 1930s.²³

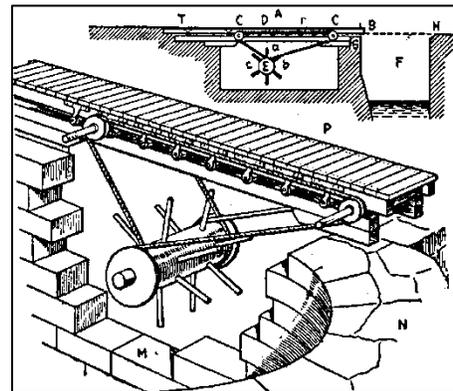
As vertical-lift bridges saw increasingly greater use during the 1930s, the competition intensified between the two leading movable-bridge design firms, Waddell & Hardesty and Ash-Howard-Needles & Tammen. Each firm put forth innovative designs to meet the demands of state highway departments and railroads desperate to increase the speed and capacity of their movable bridges.²⁴ The manufacturers of the operating machinery and electrical components were competing to develop technically superior equipment,²⁵ and the fabricating and erecting companies like American Bridge and Bethlehem were competing to reduce construction time and costs.²⁶

In 1940, New Hampshire got its second vertical lift bridge, the Interstate Bridge, later named Sarah Mildred Long Bridge, designed by Harrington & Cortelyou of Kansas City. The bridge was innovative for its tower drive lift system and the two-level bridge that combined highway above and railroad below, replacing two historic wood trestle bridges – Portsmouth Bridge of 1822 and the Eastern Railroad Bridge of 1842. In 2018 the SML Bridge as it was called for short, was replaced with an equally innovative double deck bridge of dramatic modern design.

3.4 Traversing or Retractable

According to Hovey, the nineteenth-century architectural historian, M. Viollet-le-Duc, provides evidence that retractile, or pull-back bridges were commonly built in southern France and Italy during the Middle Ages. In this type of movable bridge, the movable span is typically drawn up and over the approach span.²⁷ Bridge engineer and historian Henry Grattan Tyrell defines "traversing bridges" as "those which move back parallel to the centerline of the roadway" and "retractile bridges" as those that retreat diagonally, to one or both sides, typically over adjacent land.²⁸ The terms are used interchangeably herein.

The state has seen two examples of the type. The first draw span of the Piscataqua Bridge, built in 1794, was referred to as a "draw back" that did not perform well and was replaced by a hinged bascule. The other was a traversing plate girder railroad span added to the Sarah M. Long Bridge bridge in 1965 that utilized an uncommon overhead trolley system to move the draw span up and over the adjacent fixed span. It has been referred to as a retractable or retractile span. The type is rare with only a few examples surviving into the 20th century. The Carroll Street Bridge over Gowanus Canal in Brooklyn, built 1889, is a diagonally rolling (oblique) retractile cable-stayed girder bridge that was given landmark status in 1987 and survives today. The Summer Street "oblique retractile drawbridge" built 1899 over Fort Point Channel in Boston was replaced in 1996.²⁹



Rolling "draw-back bridge" from French text dated 1813 (Hovey, 1926).

4.0 NEW HAMPSHIRE'S HISTORIC MOVABLE BRIDGES

New Hampshire's historic movable bridges are those fifty years of age or older and therefore potentially eligible for listing in the National Register of Historic Places. Unfortunately, only two movable bridges survive that meet that criterion, both of the trunnion bascule type: New Castle-Rye Bridge, built 1942 and Hampton Harbor Bridge, built 1949. All of the state's drawbridges, large and small, tell a story of water versus land transportation and together form an important part of New Hampshire's history of settlement and development.

The settlement of New Hampshire, beginning in Rye in 1623, was largely dependent on waterborne transportation. The early towns of Portsmouth, Dover, Exeter and Hampton were all founded along coastal estuaries navigable by sailing vessels that moved people and trade. Roads developed slowly over the next century and with a few exceptions it was not until the beginning of the nineteenth century and the building of private toll roads known as turnpikes that commerce began moving about the state on wheels in economically significant ways. The state's first monumental bridge undertaking with a draw span, Piscataqua Bridge, between Durham and Newington, was erected in 1793 to connect with The First Newhampshire [sic] Turnpike then in the planning stage.

The "Great Arch" of the Piscataqua Bridge attained immediate fame as the longest span in the country. Two drawbridges predated the Piscataqua, the earliest being Puddle Dock Bridge in Portsmouth built 1731, one of the first, if not the first, movable bridge in the country. Important and very early history of railway draw bridges was also made in New Hampshire with the construction of the Eastern Railroad Bridge across the Piscataqua at Portsmouth in 1842. The Portsmouth and Dover Railroad Bridge from Dover to Newington built 1874, was equipped with a cable-stayed rim-bearing swing span that was among the first of its type designed with longer spans for new heavier locomotives. The Mile-Long Bridge over Hampton River built 1902 with a two leaf bascule draw, brought vast changes to a large section of the state's ocean frontage that became important to the state's tourism economy. In 1923, Memorial Bridge was completed in Portsmouth, a bridge of national significance to the history of bridge engineering and interstate highway transportation.

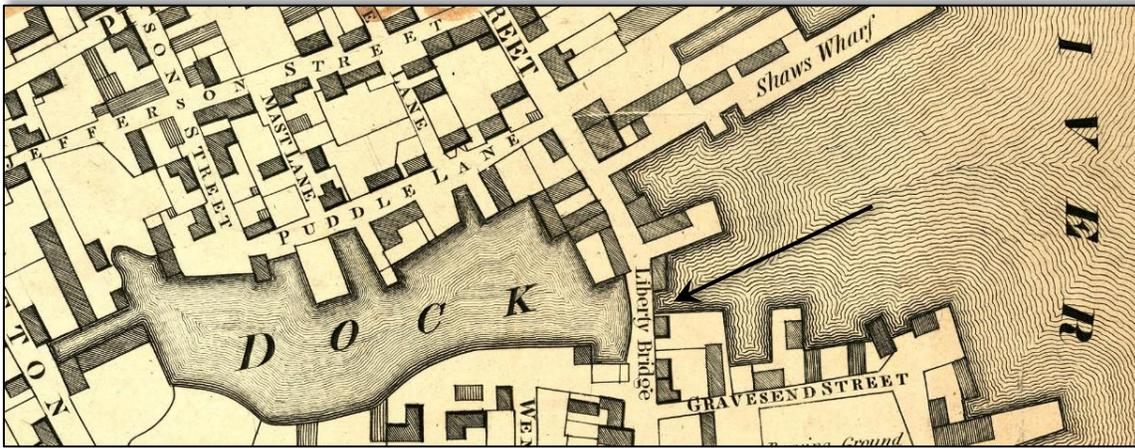
Numerous scholarly papers and reports have been written on these bridges and are referenced in the endnotes. This study has searched for the lesser-known and in some cases forgotten drawbridges that nonetheless were important to our history. It would take many volumes to tell the whole story; instead the history of each drawbridge is covered in short illustrated sections, following the summary table below. The two movable bridges recently built in Portsmouth, the new Memorial Bridge built 2013 and the new Sarah Mildred Long Bridge built 2018, are briefly discussed in the section on their predecessor bridges of the same name.

Table of New Hampshire's Historic Movable Bridges

Section	Original Name / Other Name	Years	Town	Waterway	Bridge Type	Draw Type
4.1	Puddle Dock Bridge / Liberty Bridge	1731 – 1899	Portsmouth	Inlet	Highway	Bobtail swing
4.2	Stratham-New Market "Lottery" Bridge	1773 – 1926	Stratham – New Market	Squamscott River	Highway	Hinged bascule, 2 leaf
4.3	Piscataqua Bridge	1794 – 1855	Durham – Newington	Great Bay	Highway	Traversing; Hinged bascule, 2 leaf
4.4	Portsmouth Bridge	1822 – c.1924	Portsmouth – Kittery, ME	Piscataqua River	Highway	Hinged bascule, 2 leaf (assumed)

Section	Original Name / Other Name	Years	Town	Waterway	Bridge Type	Draw Type
4.5	New Castle Bridge	1822 – 1942	Portsmouth – New Castle	Piscataqua R. channel,	Highway	Hinged bascule, 2 leaf
4.6	Eastern Railroad Bridge	1842 – 1939	Portsmouth – Kittery	Piscataqua River	Railroad & Highway	Hinged bascule; Shear pole swing
4.7	Portsmouth & Concord Railroad "Great Bay Bridge"	1852 – 1955	Newfields – Stratham	Mouth of Squamscott River	Railroad	Shear pole swing; Center bearing swing
4.8	Portsmouth & Dover Railroad "Dover Point Bridge"	1874 – 1935	Dover – Newington	Great Bay	Railroad & Highway	Cable stayed rim bearing swing; Center bearing swing
4.9	Eliot Bridge	1878 – 1950	Dover – Eliot, ME	Salmon Falls River	Highway & Street Railway	Hinged bascule, 2 leaf
4.10	Wentworth Bridge	1878 – 1942	New Castle – Rye	Little Harbor	Highway	Hinged bascule, 2 leaf
4.11	"Mile Long Bridge" / Hampton River Toll Bridge	1902 – 1949	Hampton – Seabrook	Hampton River	Highway & Street Railway	Hinged bascule, 2 leaf
4.12	Piscataqua River Bridge <i>Memorial Bridge</i>	1923 – 2013	Portsmouth – Kittery, ME	Piscataqua River	Highway	Vertical lift
4.13	Newfields-Stratham Swing Bridge	1926 – 2000	Newfields – Stratham	Squamscott River	Highway	Center-bearing swing
4.14	Bellamy River Bridge / <i>Col. Alexander Scammell Memorial Bridge</i>	1935 – 1998	Durham	Bellamy River	Highway	Bascule, 1 leaf, over road counterweight
4.15	Interstate Bridge / <i>Sarah M. Long Bridge</i>	1940 – 2018	Portsmouth – Kittery, ME	Piscataqua River	Highway & Railroad	Vertical lift; traversing span added later
4.16	New Castle Rye Bridge	1942 – in service	New Castle – Rye	Little Harbor	Highway	Trunnion bascule, 1 leaf, under road counterweight
4.17	Hampton Harbor Bridge <i>Neil R. Underwood Memorial Bridge</i>	1949 – in service	Hampton – Rye	Hampton Harbor Inlet	Highway	Trunnion bascule, 1 leaf, under road counterweight

4.1 Puddle Dock Bridge / Swing Bridge / Liberty Bridge, 1731 – 1899



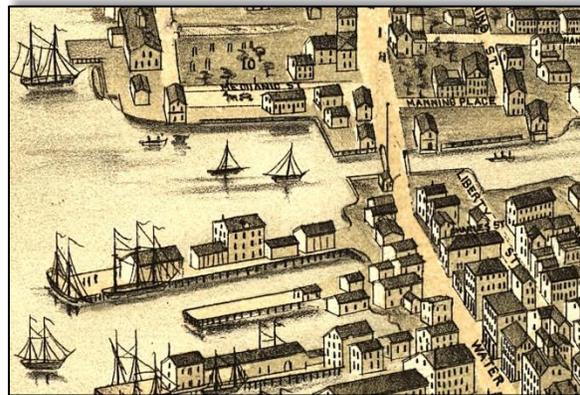
Map of Portsmouth by J. G. Hales, 1813

According to Nathaniel Adams, in his *Annals of Portsmouth*, in 1731 "the town gave permission to a number of persons to build a bridge over the cove, from Marshall's landing to Paul's, provided they would build and maintain the same at their own expense. This bridge had a hoist or draw in it for vessels to pass through, and was called Swing-bridge."³⁰ The bridge spanned a narrow inlet between the Piscataqua River and a sheltered cove with wharfing on its north side projecting from Puddle Lane. Sailing merchant vessels of shallow draft and beam under 25 feet, the width of the draw opening, could berth in the cove known as Puddle Dock.

Swing Bridge joined the streets along the water north and south of the inlet, eliminating the long route around the west end of the cove. Water Street, as it was known (now Marcy Street) became the backbone of the city's vital maritime trade.

The mechanical design of the draw has apparently been lost to history but it reportedly "swung sideways." A simple plan of the bridge held by Portsmouth Athenaeum, shows it 110' long with an off-center pivot located on the south bank of the inlet. This type of swing bridge with so-called unequal arms extending from the pivot point is known as an asymmetrical or "bobtail" swing, a type used for a single narrow waterway. The short arm that spanned the channel had to be counterweighted, sometimes accomplished with heavier framing, perhaps done in this case. Early bobtail swing bridges were typically operated from shore by sets of block and tackle attached to the end of the bridge and to pilings or other anchorages, often with the aid of a capstan under the shore-arm.

When Britain enacted the Stamp Act in 1765, American colonists were outraged. When the commission for Portsmouth's stamp master arrived in January 9, 1766, an angry mob seized the document and carried it on the tip of a sword to the bridge where it was nailed to a post along with a flag reading "Liberty, Property and no Stamps." The bridge was christened "Liberty Bridge," and survived until 1899 when the Puddle Dock cove and inlet was filled in.



Bird's Eye View map by J. J. Stoner, 1877, looking south, along Water Street showing a small gatehouse at the northeast end of Liberty Bridge.



Liberty Bridge, ca.1870s Courtesy Portsmouth Athenaeum).

4.2 Stratham – New Market "Lottery" Bridge, 1773 – 1926

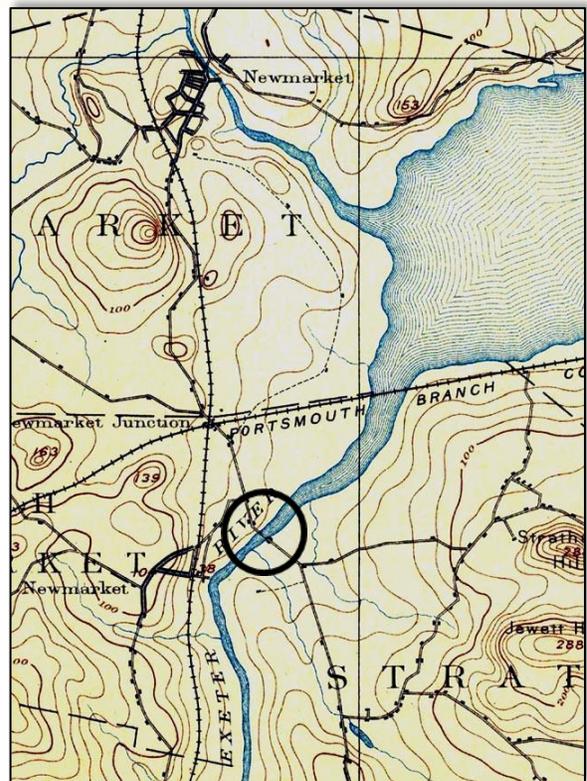


Stratham Bridge over Squamscott River, photo ca. 1920, showing the double-leaf, cable-lift bascule draw span built 1884. Courtesy Stratham Historical Society.

Exeter was settled in 1638 at the lower falls of the Squamscott River where water power was harnessed for mills. The falls marked the head of tidewater navigation of the river by way of Great Bay and the Piscataqua River.³¹ Exeter grew into a vital seaport and shipbuilding center. Large merchant vessels sailed between Exeter's docks and the ocean. In 1747 the General Court granted petitioners "Liberty to Erect and Build a Good, Strong and Convenient Bridge over the River at New Market and Stratham... [with] a Passage for Vessels, Gundelos, Rafts and other water Carriage ... [and] that a part of said Bridge be made to Draw in the most Convenient manner twenty-eight feet wide for the Passage of Vessels."³² Objections by shipping interests and lack of funding stalled progress until 1773 when a toll bridge with a draw was built following a successful lottery. A new toll bridge with new owners was constructed in 1807.

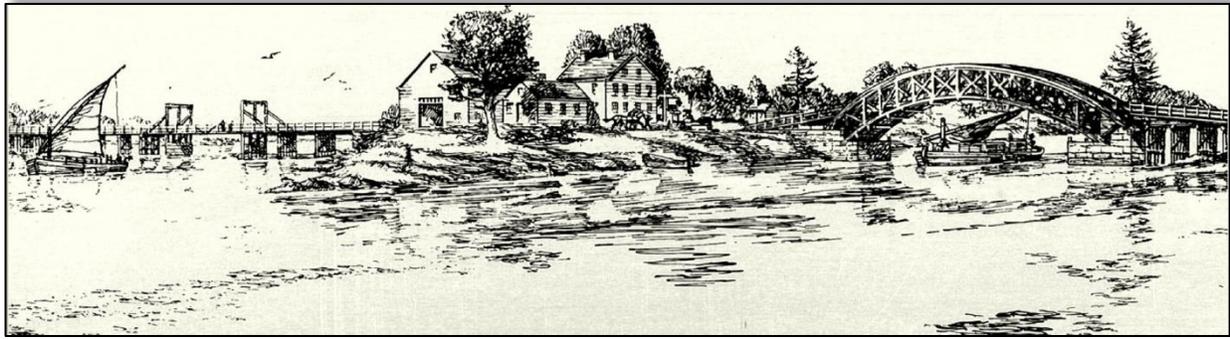
When the Piscataqua Bridge over Great Bay collapsed in 1855, traffic along the First New Hampshire Turnpike between Concord and Portsmouth was detoured over the Stratham Bridge until the opening of the Dover Point Bridge in 1874.

In 1884 the bridge was rebuilt and equipped with a new draw. *Granite Monthly* magazine pictured and described the bridge in 1899 as entirely of wood construction with a double-leaf draw span flanked by pile-supported approaches extending into the channel from stone abutments. The draw spans were of the bascule type, hinged at the deck and drawn open by ropes, cables and counterweights suspended from timber framework above the roadway. In 1911, the river was dredged to provide a 40-foot wide, 6-foot deep navigation channel and in 1926 the entire bridge was replaced by the New Hampshire Highway Department (NHHD) with a steel plate-girder bridge with a swing span (described in Section 4.13).



Dover topo map, 1893, showing Stratham Bridge, originally known as Lottery Bridge, crossing the Squamscott River, called the Exeter River at that time.

4.3 Piscataqua Bridge, 1794 - 1855



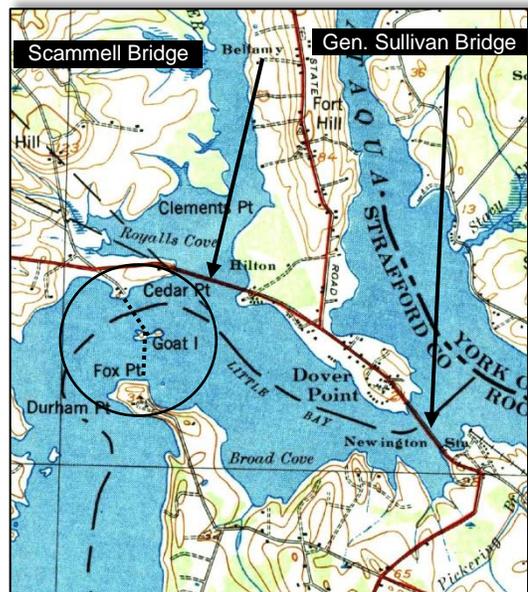
Sketch of Piscataqua Bridge by John Frink Rowe. At right is the famous "Great Arch; at left is the section from Goat Island to Tuttle Point (Cedar Point) in Durham that consisted of a 900-foot long oak pile trestle with a draw span. The original draw designed by Zenos Whiting of Norwich Connecticut was a referred to as a "draw-back" span, a rarely used type also known as a traversing or retractile draw. It functioned poorly and after two years was replaced with a double-leaf hinged bascule draw, depicted in the sketch above. The spans were opened with block and tackle passed over upright frames. Courtesy of Town of Newington.

The Piscataqua Bridge is perhaps New Hampshire's most famous and important bridge and much has been written about it (see endnote for sources of information).³³

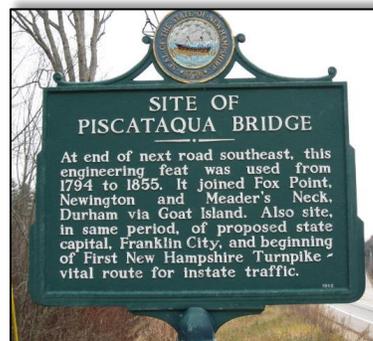
The Proprietors of Piscataqua Bridge were incorporated on June 20, 1793 "for the purpose of building a Bridge over Piscataqua River between Bloody Point and Furber's Ferry, so called, and for supporting the same."³⁴ The rationale for such an unprecedented undertaking was to increase travel and trade between Portsmouth and the rest of the state and collect the tolls resulting. But the larger purpose of several of the bridge proprietors and their associates became evident three years later when they chartered the New Hampshire Turnpike Road to make "communication between the Sea-coast and the interior parts of the state...much more easy, convenient and less expensive by a direct road from Concord to Piscataqua Bridge, than it is now..."³⁵ The state's first turnpike opened in 1801, providing some investors with returns from both bridge and highway tolls.

The bridge was built in three sections between two islands. From Fox Point in Newington to Ram Island was a 600-foot oak pile trestle, notable for the water depth of 54 feet. From Ram Island to Goat Island was a wooden arch designed by Timothy Palmer with a span of 244 feet. The third section with a draw span is described in the caption above.

Palmer's "Great Arch" as it was known, consisted of three trussed girders roughly 20' deep. One girder ran down the center creating separate travel lanes, each roughly 16' wide. The bridge was immediately famous and the arch stood as the longest span in the country until 1812 when Lewis Wernwag's 340-foot Colossus Bridge was erected over the Schuylkill River near Philadelphia.



The bridge ran between Durham and Newington via Goat Island, shown by the dashed lines on this 1941 topo map. The opening of the Gen. Sullivan and Col. Scammell bridges along with Route 4 in 1935 reestablished the route of the First NH Turnpike from Portsmouth to Concord, lost when Piscataqua Bridge collapsed in 1855.



Cyrus Frink of Newington, a skilled builder who operated a tavern near the bridge and had maintained and repaired the structure many times for the proprietors, was commissioned to completely replace the arch in 1818. It stood until 1844 when it was replaced with another arch designed by his son Elias which stood until 1854. The following year an ice jam demolished other sections of the bridge and having lost profitability due to competition from the Portsmouth Bridge and railroads, it was not repaired and reopened.



Sketch of early double-leaf hinged bascule bridge located in Chicago, 1820 (Becker 1942). Hinged bascules were often equipped with counterweights of stone or iron hung from ropes over the uprights to assist in raising the spans with block and tackle, a winch or capstan.



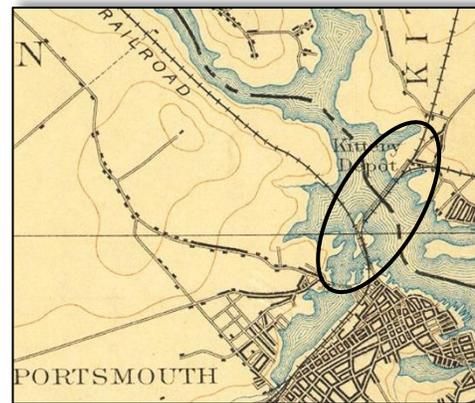
Map of Newington prepared by Richard Dame, 1805, located in the New Hampshire State Archives, showing Piscataqua Bridge and the "Road from Piscataqua Bridge to Portsmouth."

4.4 Portsmouth Bridge, 1822 – c.1924

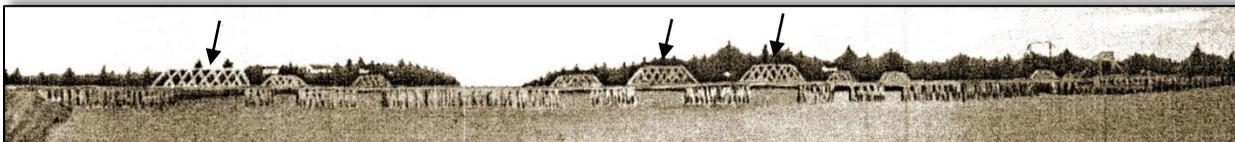


Portsmouth Bridge was a wood pile trestle highway bridge that stretched 1600 feet across the Piscataqua from Portsmouth to Kittery. Extreme currents, tidal range and depth of water made the bridge a monumental undertaking few thought feasible. This photo, ca. 1885, courtesy of Portsmouth Athenaeum, shows the downstream side of the Eastern Railroad trestle, built 1842, immediately alongside the Portsmouth Bridge.

The Proprietors of Portsmouth Bridge incorporated in 1819 to bridge the Piscataqua River between Portsmouth and Kittery, Maine. Cyrus Frink of Newington, who had distinguished himself as the preeminent bridge builder in the region by reconstructing the Piscataqua Bridge on several occasions, built the bridge in five months and opened it in September 1822. It was equipped with two draw spans, each 35' wide, one at the west end between Ringe's Wharf and Nobel's Island and one at the east end near the Kittery shore. The "draw or hoist" as they were called are not described in the literature but were almost certainly like other early draws in the area consisting of a single or double-leaf bascule, hoisted with block and tackle drawn over tall pilings or timber frames above the roadway. They may or may not have had a counterweight system.³⁶ Over the main channel there was a 50'-wide opening called "the arch" with 15 feet of clearance at high tide. The rest of the structure was of typical wood pile trestle construction consisting of bents of six or more piles spaced about 12-15 feet apart. The bridge impaired navigation and within two years the Legislature was hearing petitions from citizens of the towns upstream demanding alterations be made for easier passage.

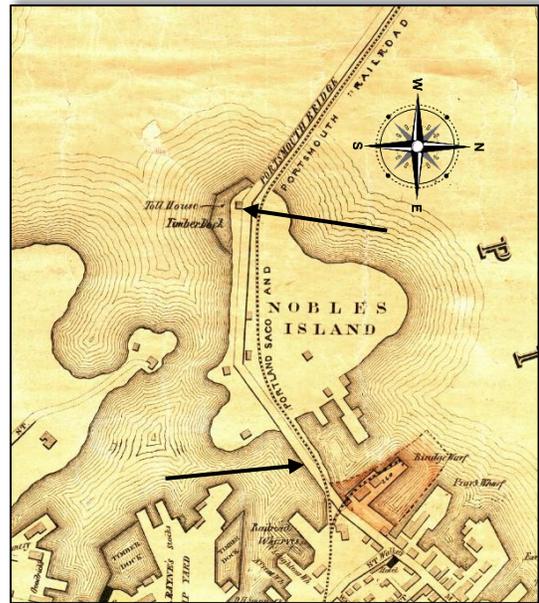


Bridge location circled on 1893 topo map, crossing the Piscataqua River in two sections, from the north end of Market Street to Noble's Island (previously known as Ham's Island), and then across the main part of the river to Kittery, Maine.

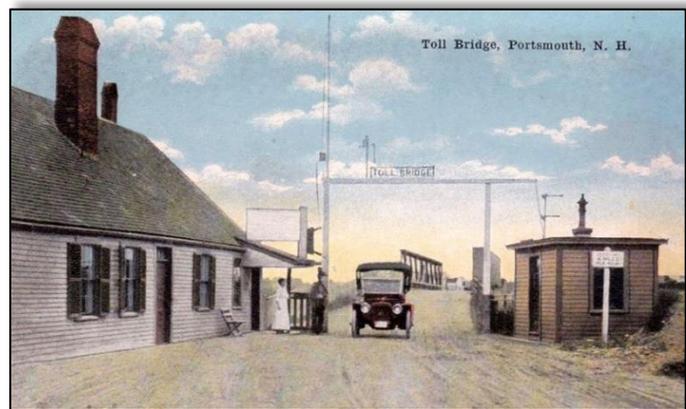


Navigators forced changes to the bridge in 1826 including widening the main opening from 50' to 70' and adding two additional 70' openings (arrows). The draw was widened and planking added to openings (fenders) to prevent boats from snagging. The two draws were widened to 40' in the late 1830s. A mooring buoy was anchored upstream of the bridge for vessels to make fast and wait for favorable conditions to pass the bridge safely. Nine or more additional openings under a variety of truss types seen in this early sketch of the bridge were added at some time. By 1840 repairs and improvements totaled \$30,000, equal to the original cost of the bridge. Courtesy Old Berwick Historical Society.

Following the incorporation of the Eastern Railroad in New Hampshire in 1836, the railroad's owners began negotiations to purchase or lease the Portsmouth Bridge with the intent of widening it to carry their line across the Piscataqua River to make connection with the Portland, Saco and Portsmouth Railroad in Kittery. But before a deal could be struck the current undermined a stretch of pilings and pushed the bridge out of alignment as much as seven feet. In 1839, to protect their investment, the bridge owners began dumping hundreds of tons of stone around the base of the pilings to prevent their movement. In 1840 the town of Dover sued the Proprietors of Portsmouth Bridge in a desperate effort to stop the Eastern Railroad from completing their crossing of the Piscataqua (see next section, Eastern Railroad Bridge). The suit moved too slowly and in 1841 an agreement between the railroad and the bridge owners to jointly operate a combined highway and railroad bridge was reached and approved by the Legislature with the condition that the enlarged structure could not "obstruct, impede or injure the free and unobstructed navigation" beyond that allowed in the original bridge charter of 1819.³⁷ Construction commenced soon after passage of the law in June and the bridge was completed and opened in November 1842. The highway bridge remained in service until shortly after the opening of the US Route 1 Memorial Bridge in downtown Portsmouth in 1923. Photos taken during the construction of the new Interstate Bridge (Sarah Mildred Long Bridge) in 1939 show a dilapidated and partly dismantled structure; the entire structure along with the adjoining railroad trestle was demolished in 1942 after the completion of the Interstate Bridge.³⁸



Map of Portsmouth, 1850, by H.F. Walling, showing the Portsmouth Bridge with the railroad bridge along the downstream side. Upper arrow points to the toll booth in postcard below; lower arrow points to location of draw span in pile trestle to the island, it was not a solid causeway as suggested by the map.



Postcard, ca. 1912, of toll house and gate at the Portsmouth end of the bridge. Courtesy of Portsmouth Athenaeum.



Construction of the Interstate Bridge alongside the Portsmouth Bridge in 1939. The remains of the highway portion of the bridge, closed with portions of the deck removed is seen at left with the still functioning Boston & Maine Railroad line next to it showing they were independent abutting structures. Courtesy Portsmouth Athenaeum.

4.5 Newcastle Bridge, 1822 – 1942

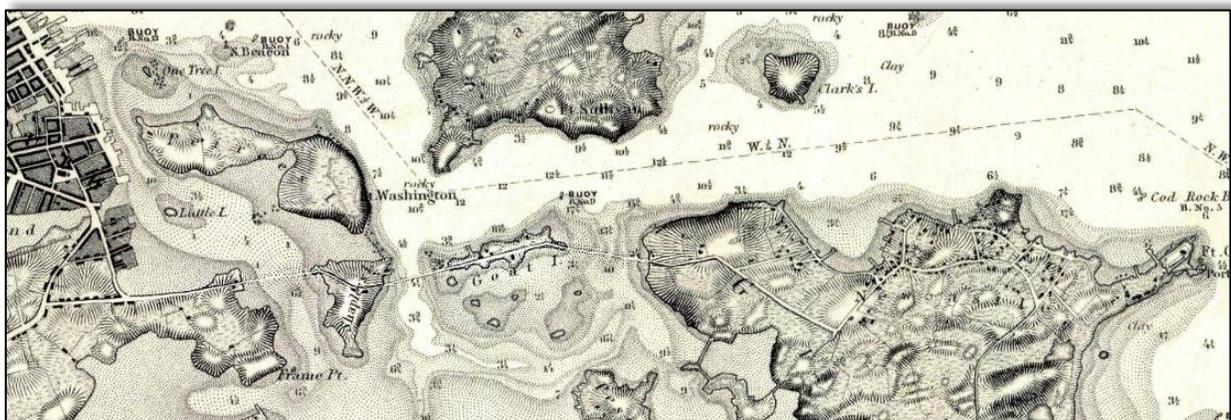


View of the middle trestle of the bridge looking from Shapleigh Island toward Goat Island, taken July 3, 1940 by NHHD bridge inspector Wendell H. Piper. The 28' draw span was located eight bents out from the west abutment. No plans for the draw are known to exist but based on photographs it appears as a double-leaf hinged bascule, manually operated with pulleys and counterweights suspended from pile towers, seen painted white above. Compare to c. 1910 postcard below.

After several failed attempts between 1759 and 1820 to maintain a profitable toll bridge at the southwest end of the island between Newcastle and Rye, a new group of investors organized again under the same name used twice previously – *The Proprietors of Newcastle Bridge*.³⁹ They incorporated in 1821 "to erect and maintain a Bridge from the Northwest end of the Island of New Castle to the town of Portsmouth across the waters and connected with any of the Islands lying on the Southerly side of the Channel of Piscataqua river."⁴⁰ The law required a "draw or hoist in said bridge, shall be constructed, over the channel of what is called the Pool of sufficient width for vessels to pass and repass freely." Among the proprietors were Ruben Shapleigh, (also spelled Shapley) and Ephraim Amazeen who owned islands along the proposed route.



Portsmouth-Newcastle Bridge on the 1858 Chase map, originally consisted of three pile trestles. The middle trestle had a bascule-type draw, removed in 1941.



Water Street in Portsmouth (later Marcy Street) was extended out Frame Point along what is now New Castle Avenue, shown on the 1854 U.S. Coast Survey map. The deeper channel between Shapley and Goat Islands included a draw.

The bridge was "erected under the superintendence of Mr. Mark Loughton, in the short space of five months."⁴¹ Upon opening in January 1822 it was described "as being in three parts; the first extends from the south end [of Portsmouth] to Shapleigh's island is 849 feet in length; second, from Shapleigh's island to Amazeen's island [now Goat island], 718 feet, third, from Amazeen's island to Great island [now Newcastle], 809 feet, making whole bridges 2371 feet in length. Bridge built upon piles except long abutments at each shore. Whole cost eight thousand dollars."⁴²

The bridges were undoubtedly repaired many times with major reconstructions done in 1910 and again in 1926 after the state took over ownership. The greatest changes to the bridge were made in 1941-42 as part of the World War II coastal defense program known as the Portsmouth Harbor Defense Area. Bridges and roads along the east coast were upgraded to supply coastal military operations and batteries, including Fort Stark, Fort Constitution and Camp Langdon on New Castle island. With federal funds and plans approved by the War Department, the NH Highway Department replaced 75% of the west and middle trestles increasing their load capacity to carry 10-ton trucks.⁴³ The draw span was removed and clearance under the bridge increased three feet over the channel. The east trestle from Goat Island to New Castle was eliminated and the roadway moved onto a stone breakwater built by the Army in the 1880s (photo below).⁴⁴

In 1955 the two remaining trestles were replaced with steel I-beam stringer bridges with concrete decks which remain in service today.



Above: Postcard, c. 1910, of middle trestle of the bridge with draw span. Courtesy of NH Port Authority.

Below: West approach to middle trestle of the bridge taken July 3, 1940 by NHHD bridge inspector Wendell H. Piper.

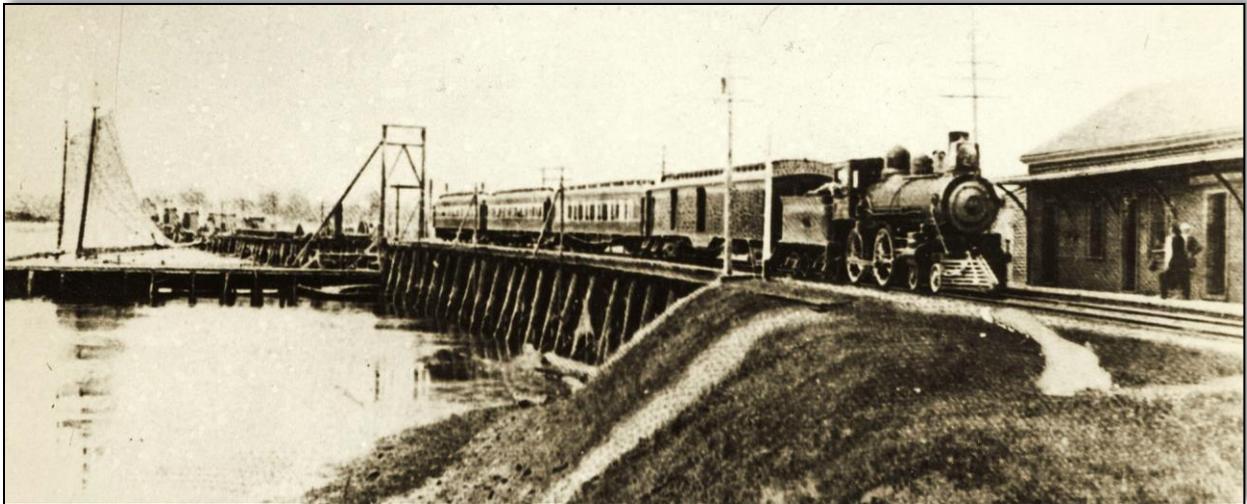


Toll House at Portsmouth end of the west trestle in undated photo courtesy of NH Port Authority. In 1925 the Legislature passed a bill (Chapter 147) providing for the establishment of a trunk line highway starting at the intersection of Sagamore Ave. and Wentworth Rd. in Portsmouth, extending through Rye and over Wentworth Bridge, through Newcastle and over the three bridges to New Castle Ave. in Portsmouth. The two towns and the city jointly acquired title to the bridges from the Proprietors of New Castle Bridge, lifted the tolls on August 7, 1926 and transferred ownership to the state. Photo courtesy of NH Port Authority.



During World War II the old military forts on New Castle Island were reactivated to defend Portsmouth Harbor. Heavy trucks loaded with building materials and military supplies greatly exceeded the capacity of the wood trestle bridges to the island. The trestle between Goat Island and New Castle was bypassed with a gravel-filled causeway seen completed at left. Photo courtesy of NH Port Authority.

4.6 Eastern Railroad Bridge, 1842 – 1939

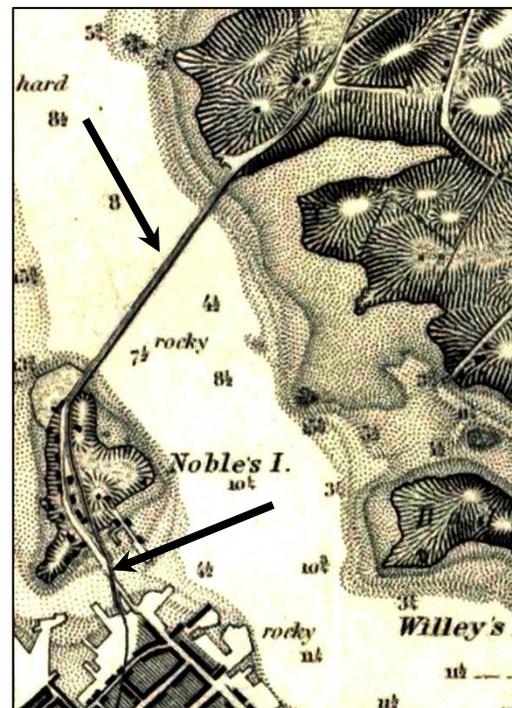


Eastern Railroad train crossing the Piscataqua River bridge from Portsmouth and arriving at the Kittery Depot. Behind the train is an upright shear-leg or "shear-pole" framework that supports the swing draw when it is opened. Another shear pole swing draw was located at the west end of the bridge between Noble's Island and the shore. Courtesy of Portsmouth Athenaeum.

In the late 1830s railroad investors intent on connecting the ports of Boston and Portland coalesced into two competing ventures. The Boston & Portland RR (later part of the huge Boston & Maine system) chose the "Upper Route" through Haverhill that entered New Hampshire at Plaistow, ran west of Great Bay by way of Exeter, Durham and Dover to enter Maine at South Berwick. The B&M line was completed to Dover in 1840 but ultimately did not connect to Portland until February 1843. Meanwhile the Eastern Railroad laid out a shorter coastal "Lower Route," through Newburyport, Hampton and Portsmouth, where it planned to cross the Piscataqua River to Kittery alongside the Portsmouth Bridge on its rights granted in 1819.

Dover capitalists and merchants invested in the B&M coming to town panicked at word of negotiations between the Eastern RR and the Proprietors of Portsmouth Bridge (Proprietors). The Portsmouth Bridge had proved a pile trestle could be anchored in the deep river and withstand its fearsome currents and ice, so there seemed little to stop the Eastern. Once the Eastern was over the river and joined with the Portland, Saco and Portsmouth RR that was building to meet it, much of the banked-on trade with the thriving port of Portland was feared lost.

In an effort to stop construction of the railroad bridge, a lawsuit was filed in New Hampshire Superior Court by the town of Dover against the Proprietors, claiming Portsmouth Bridge impeded navigation to Dover's seaport causing damage to Dover's income and property. Dover wanted nothing less than the existing bridge removed. Testimony left little doubt that many merchant sailors trading with Dover had lost boats, cargo and even lives by missing the bridge openings, being driven against the pilings and swamping or capsizing.⁴⁵

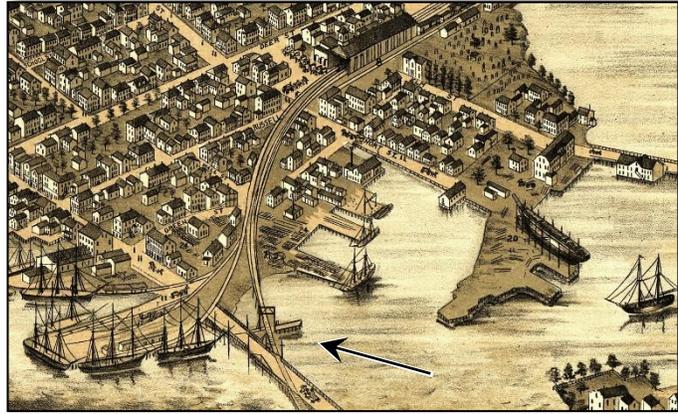


Coastal Survey map of Portsmouth Harbor, 1866. The Eastern Railroad built their pile trestle bridge against the downstream side of the existing 1822 Portsmouth Bridge, duplicating the openings for vessels in order to maintain the established navigability of the old bridge as ordered by the court. There were two draw spans, one at each end of the bridge (arrows).

The court however, found the bridge to have been built to the terms of the original charter and refused to stay construction of the railroad bridge while the case was being heard. In November 1842 the bridge opened, completing the connection with Portland three months ahead of the B&M.⁴⁶ In July 1845, the court finally ruled in favor of the Proprietors. The opinion, written by Chief Justice Joel Parker, added importantly to New Hampshire case law, in particular the state's "entire sovereignty" over navigable waters within its limits. Dover's fears were allayed as the more powerful and competitive B&M eventually cornered eighty percent of Maine traffic, driving Eastern to bankruptcy in 1875 and then leasing it into the B&M system in 1885.

The bridge was repaired and modified many times during the late 19th and early 20th century including strengthening and widening the draw spans.⁴⁷

Shortly after the opening of the Memorial Bridge in 1923 carrying the new U.S. Route 1, the railroad closed the highway portion of the bridge and utilized it as a work platform for maintaining the railroad bridge.⁴⁸



Bird's Eye View map of Portsmouth, 1877, with a depiction of shear pole draw span in the section of the Eastern RR Bridge bridge between the city and Noble's Island. The draw was replaced in 1913 as was the main draw in the river near the Kittery shore several years later.



Photo of the main draw span near the Kittery shore taken in 1939 during construction of the Interstate Bridge that was being built to replace it. At center is the timber-framed shear leg (or shear pole) lifting tower from which the swing span was suspended when open. A single set of shear legs are supported with wire rope guys attached to the top of the tower and back to anchor points on the bridge. Here a second set of shear legs is used forming a square tower carrying an elevated platform on which the hoisting machinery is mounted (see additional photos below). Pile bents extend out perpendicular to the bridge on the east side of the draw opening, as a fender system and to support the diagonal shear leg that assists in carrying the load of the open draw span. The draw span consisting of a timber deck truss, visible left of center supported by lift cables, is anchored to a pivot at the end under the shear tower and swings out at a right angle over the adjacent fender system. The draw above was installed in 1913 and took ten to twelve men 30 minutes or more to open and close, often causing train delays and long traffic backups. The problem grew worse each year and in 1918 the B&M finally installed electric motors to operate the draw, something they had done on their Dover Point Bridge and Portland draws in 1909. Courtesy of Portsmouth Athenaeum.

Tragedy struck September 10, 1939 when a B&M engine, tender and coach broke thru the bridge and carried the Engineer John K. Beatie and Fireman Charles D. Towle to their death in 70 feet of water. The 123-ton locomotive was determined too difficult and dangerous to salvage and instead the railroad opted to dissolve the engine by electrolysis. The B&M decided not to repair the bridge since the new Interstate Bridge, then under construction, would be open in less than a year. Traffic was rerouted through Dover. Courtesy of Portsmouth Athenaeum.



Main draw span viewed from the Kittery shore in 1939. The bridge was closed due to the collapse. At right the deck of the highway bridge can be seen carrying several sheds presumably being utilized as shelters for workers or tool storage. Courtesy of Portsmouth Athenaeum.



The main draw span taken from the end of the downstream fender pier (Openo 1988). The shear leg tower was built with a skew that facilitated swinging the draw span open where it hung suspended over the walkway at lower right



4.7 Portsmouth & Concord Railroad "Great Bay Bridge," 1852 – 1955

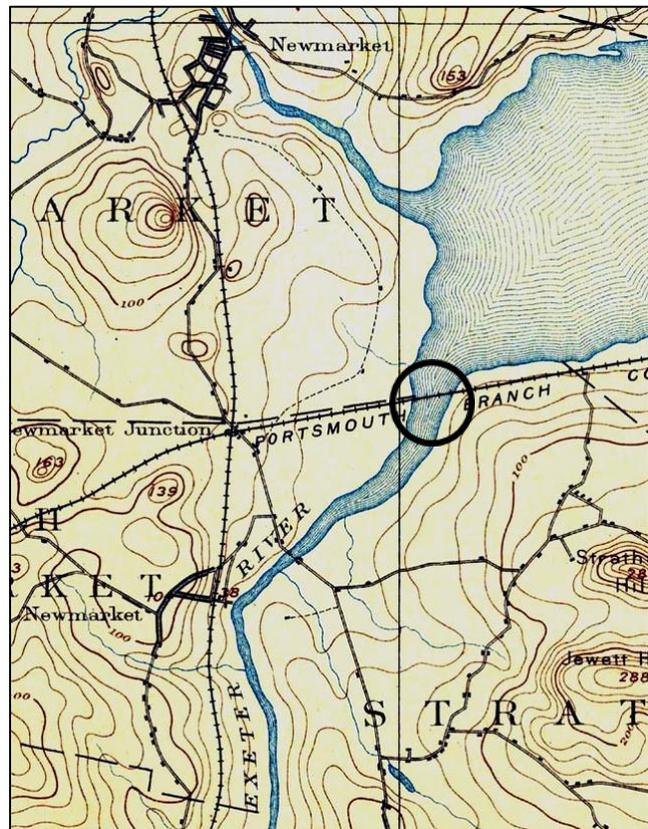


View of bridge ca. 1920, from schooner *Ada J. Campbell* being towed down the Squamscott River to Great Bay by tug *Ida* of Dover. The draw span, known as a shear pole or shear leg swing, has been swung open on the bay side, suspended by cables from the upright frame tower (Stratham Historical Society).

The Portsmouth and Concord Railroad (P&C) was built to transport textiles and other manufactured goods from Concord and Manchester to Portsmouth for export.⁴⁹ The line opened in 1852, connecting terminals shared with the Eastern RR in Portsmouth and the Concord RR in Concord. A branch from Candia to Manchester was completed in 1862. About seven miles west of Portsmouth the line crossed the mouth of the Squamscott River at Great Bay. Exeter, located upriver at the head of navigation, was an active seaport; large vessels sailed the river, necessitating the construction of a draw bridge. The line intersected the Boston & Maine RR (B&M) one mile west of the bridge where a depot was erected, known as New Market Junction and later Rockingham Junction. The P&C was taken over by the Concord & Montreal RR in 1885, and by the B&M in 1895.

The draw span of the bridge was a shear pole – also called a shear leg – swing draw, a common type used by railroads during the mid-19th century. Unsuitable for long spans or double-track lines, few if any exist today.

The first Eastern Railroad bridge from Portsmouth to Kittery, built 1860, was equipped with a shear pole swing of similar design for the draw opening. The Eastern RR draw was later rebuilt with a longer span and a heavier double shear-leg tower, but it could not be determined if the P&C span was similarly upgraded.

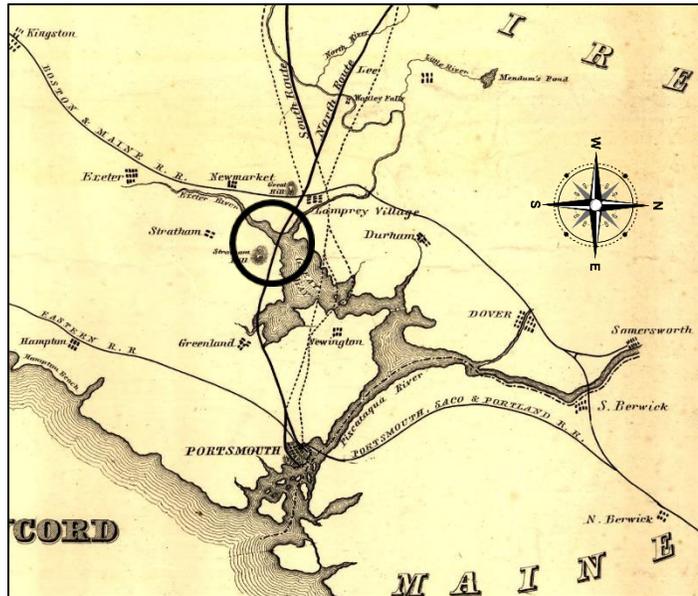


Bridge location circled on 1893 topo map, crossing the Squamscott River (labeled Exeter River on the map) just east of Newmarket Junction where the line crossed the B&M RR. At the time, the line was owned by the Concord & Montreal RR and known as its Portsmouth Branch; the designation was also used by the B&M who took over the line in 1895.

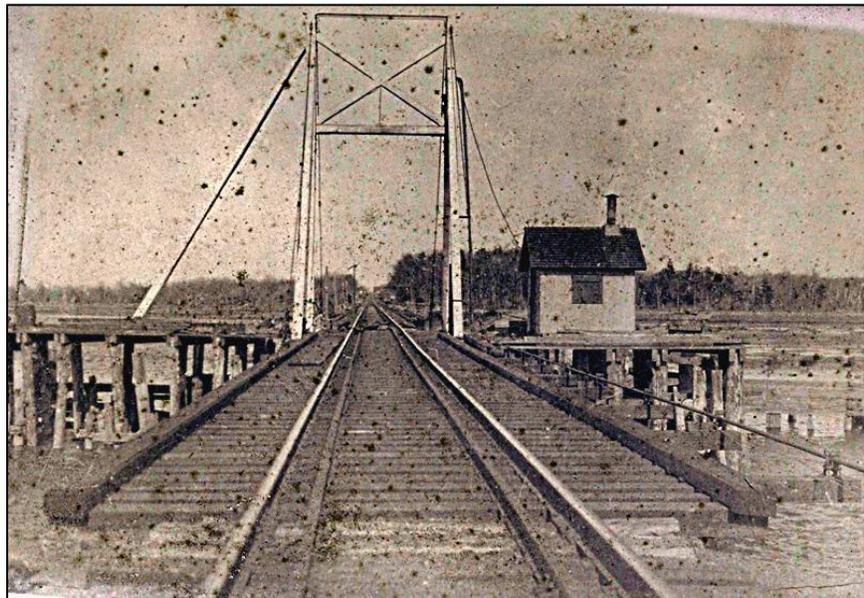
According to the 1953 B&M Bridge List the bridge spans Great Bay on the Portsmouth Division. The Pile Trestle is Bridge No. 8.65, 244 feet long overall and a date of 1941. The draw is listed as Bridge No. 8.69, with a clear span of 32 feet and a date of 1939. The bridge number corresponds to the track mileage measured west "from the track switch in Portsmouth." The bridge date refers to either the date of original construction or the date of the last major repair or replacement; no details regarding the nature of the work done to the spans in 1939 and 1941 was obtained.

As ridership and profits declined in the 20th century, B&M switched to running more cost-effective self-propelled gas-electric passenger cars on the line known as doodlebugs. Scheduled passenger service ended in 1954 and that year the B&M applied to the Army Corps of Engineers for permission to convert the draw span to a fixed span. The request was granted and the draw was replaced with girder spans in 1954 or 1955.

The B&M filed for bankruptcy in 1970, emerging in 1983 when it was purchased by Guilford Transportation, a company founded by Timothy Mellon of the famous Pittsburgh investment and banking dynasty. Guilford became PanAm Railways in 2006 and continues to operate trains over the P&C line between Rockingham Junction and Portsmouth.



Bridge location circled on *Map of the Portsmouth and Concord Railroad, November 1845*. West of New Market Junction, where the line crossed the B&M RR, the line splits into the "North Route" to Concord and the "South Route," to Manchester. The "Exeter River" above, is now called Squamscott River between Great Bay to the "lower dam" in Exeter. The freshwater section above the dam is still called Exeter River.



Glass-plate photograph of Portsmouth & Concord Railroad bridge, undated, looking east, showing the timber-framed shear leg (or shear pole) lifting tower that suspends the swing span when open. Shear leg lifting devices are an ancient multi-leg version of the gin-pole and take many forms such as A-frame derricks erected on land or on barges. The legs are supported with guys of iron or wire rope, attached to their tops and back to an anchor point on the ground or structure on which they are mounted. Here, both vertical and angled shear legs carry the load of the draw span. Pile bents extend out from the bridge on both sides of the draw opening, as a fender system and to support a diagonal shear leg (at left) that assists in carrying the load of the open draw span. The draw, anchored to a pivot at one end, swings out at a right angle over the adjacent fender system. See Section 3.0 for additional information on shear pole drawbridge history and technology (Photo courtesy of Stratham Historical Society).

4.8 Portsmouth & Dover Railroad "Dover Point Bridge," 1874 – 1935

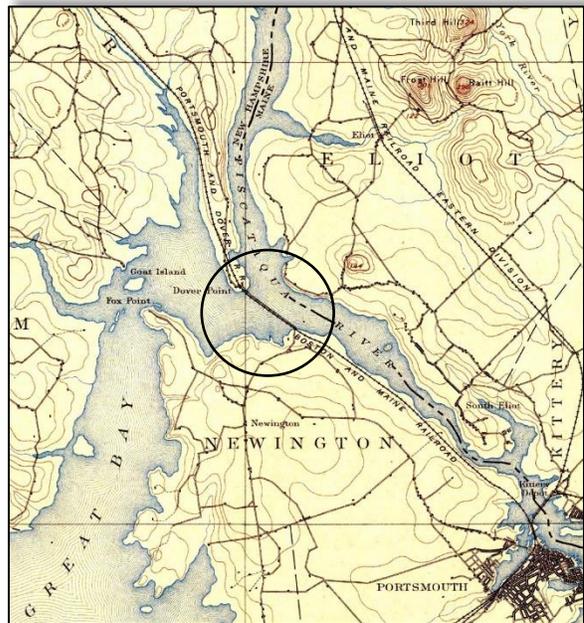


Portsmouth & Dover Railroad's "Dover Point Bridge" over Great Bay, a wood pile trestle 1600' long with a 180' covered "steel truss" span on granite piers for small boats and ice to pass and a swing span for fixed-mast vessels. Courtesy Dover Public Library.

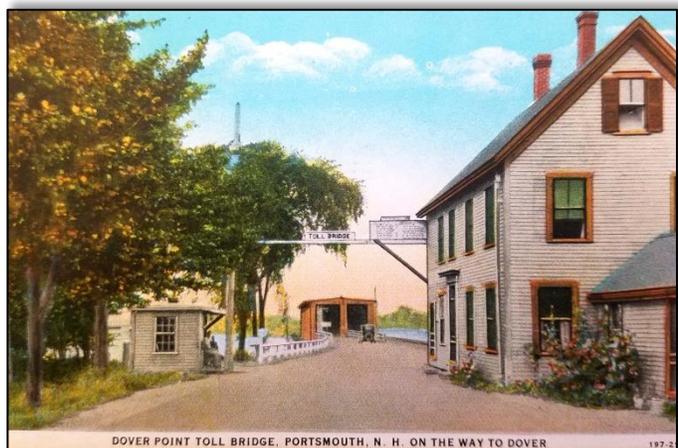
The Portsmouth & Dover Railroad (P&D) and the bridge over Great Bay was built in 1873 and opened February 1, 1874. It not only joined the two cities with a direct 10.8 mile rail line, but it reestablished a highway link across the bay lost in 1855 when the great Piscataqua Bridge between Durham and Newington collapsed, severing the route of the First New Hampshire Turnpike between Concord and Portsmouth. Frank Jones, a prominent merchant, brewer and former mayor of Portsmouth, was founder and president of the P&D and pushed the long-sought project over the finish line. As a major stockholder of the Eastern Railroad, Jones negotiated the lease of the P&D to Eastern upon its completion. When the Eastern was in-turn leased to the Boston & Maine Railroad (B&M) in 1884, Jones was made a director and became its president in 1890.

Tidal currents at the bridge were dangerous. An 1898 petition to mark the opening under the main span with lights, noted that "many lives have been lost from boats crashing against the bridge." Sixteen years later after passage of navigational-safety regulations, lights were installed on the trestle, main span and draw span of both the Dover Point and the Portsmouth-Kittery bridges.

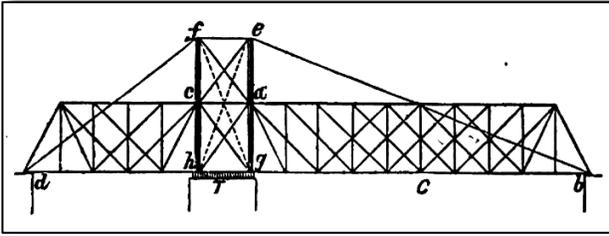
The original draw span consisted of a cable-stayed timber Howe truss swing span with 50' channel openings on each side. The draw span was likely based on Squire Whipple's designs that used a timber-frame tower at the center to which steel cables, or stays, were anchored to support the ends of the span when open. Early railroad swing bridges like this were of the rim-bearing type with the draw span carried on a circular girder called a drum, about equal in diameter to the width of the bridge, which is supported along its bottom rim by a continuous



Location of Dover Point Bridge, carrying both railroad and highway over Great Bay to Newington, shown on 1893 topographic map.



South end of bridge, showing the separated lanes of the covered truss span, with the railroad on the east side and highway on the west side (Dover Public Library).



Cable-stayed Whipple Truss swing draw with unequal arms (bob-tail swing) from Squire Whipple's 1873 *Practical Treatise on Bridge Building*. Iron and steel trusses that exhibited less flex than wood trusses eliminated the need for support towers and cables.

series of wheels. The wheels roll along a steel rail mounted along the outer edge of the support pier. The draw was opened and closed manually by one or more tenders turning a gear or cable driven mechanism, a slow, hard process that took 30 minutes or more.

The swing span was replaced in 1907 with a stronger wood truss and improved swing mechanism of unknown design and replaced again in 1914-1915 with a steel Warren-truss swing span with a motorized opening mechanism. During the latter work the entire bridge was rehabilitated.

The bridge was continually subject to fires and ice damage that closed the bridge for repairs. The worst disaster was on March 14, 1918 when the 3-foot thick ice pack in Great Bay was lifted and broke up by an exceptionally high tide. A 350-foot section of trestle south of the draw pier was torn away without warning. Newington shipyard workers spotted the massive bridge section heading south on the outgoing tide and telephoned alarm to the station agents to close the bridge.

Commander of the Navy yard Admiral Bouch, ordered the tug

Pennacook to stop the wreckage from crashing into the Portsmouth Bridge. The tug raced upriver but was forced back by the ice. Piles carrying the highway on the upstream side of the bridge were crushed by ice but the railroad trestle stood firm. The Dover bridge wreckage broke into pieces and when tide slackened shipyard workers lassoed a large section and anchored it to the Newington shore, the *Pennacook* caught a large section and workers from shore and boats hooked smaller pieces. Two sections, 40' and 25' long, somehow passed through the Portsmouth Bridge and on the next outgoing tide were laid up against the second Newcastle Bridge which was feared lost but ultimately survived with minor damage.

The B&M Railroad, still under the wartime control of the US Railroad Administration, announced they would not rebuild the highway portion of the Dover Point Bridge because the tolls were insufficient to compensate an outlay of \$50,000 in repairs and expenditures not directly related to the operation of the railroad were not allowed. The state was pressured to purchase the bridge but balked and instead pressured the Railroad Administration to allow the repairs which it did in April. Meanwhile, motorists were detoured over the Stratham and Eliot Bridges. The highway section was repaired first and opened June 20, 1918; the railroad reopened three weeks later on July 12. In 1934 the Dover Point Bridge was demolished and replaced by the General Sullivan, discussed in the section on Bellamy River Bridge, a part of the project.

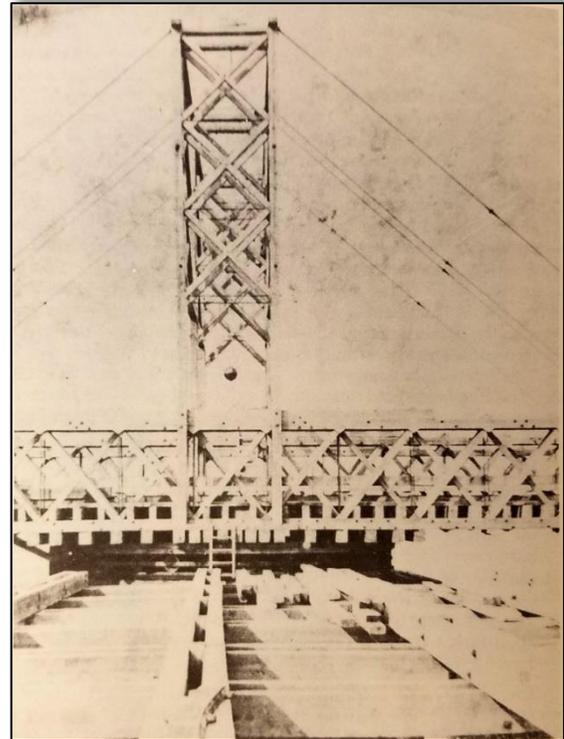
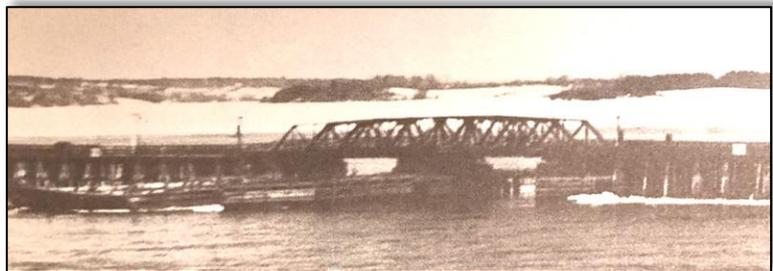


Photo of the first draw of the Dover Point Bridge in the open position during construction, ca. 1873. Note iron rod or steel cable stays anchored to the tower at the middle of the span over the pivot pier. The stays were attached to the ends of the swing arms to lend support.



Dover Point Bridge, photo c. 1934, showing steel swing span installed 1915. Courtesy Dover Public Library.

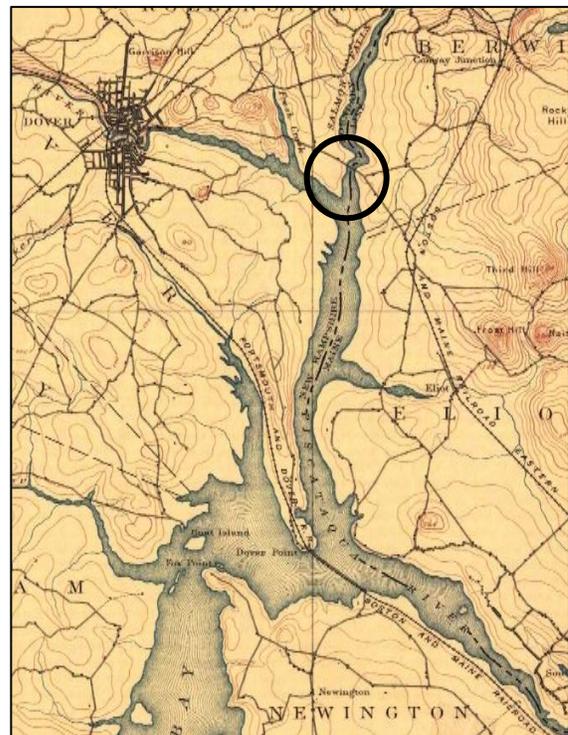
4.9 Eliot Bridge, 1882 – 1950



Eliot Bridge about 1898, looking toward the Dover shore, showing double-leaf bascule draw span. Courtesy Dover Public Library.

Eliot Bridge Company was incorporated in 1878 to erect a toll bridge over Salmon Falls River between the towns of Rollingsford, NH and Eliot, ME.⁵⁰ The law required "a Draw or Hoist in said bridge shall be constructed over the channel of said river, of sufficient width for vessels to pass and repass freely; and the said Company shall cause the same to be opened or hoisted without delay for the accommodation of all vessels as may have occasion to pass through the same."

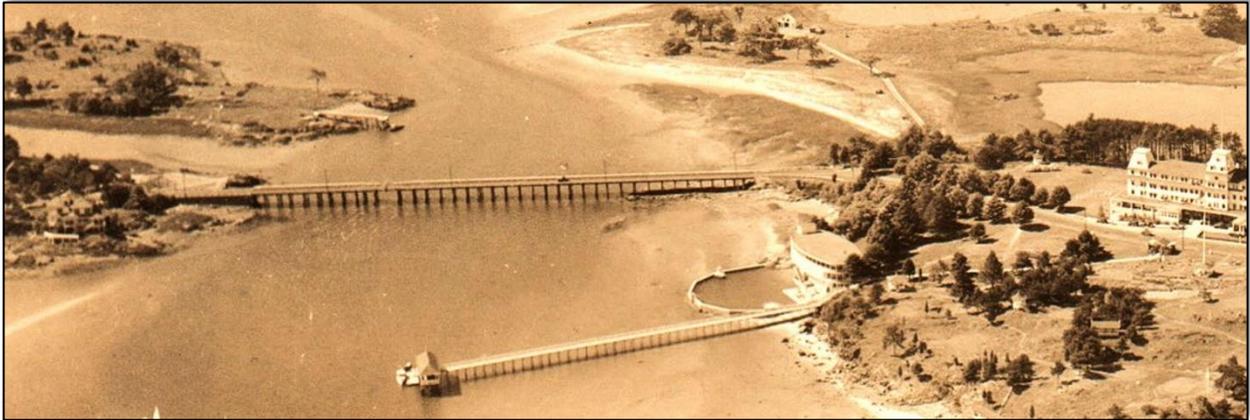
Completed in 1882, the bridge actually landed in South Berwick, Maine, but the goal was to better connect Dover with Eliot and the name Eliot Bridge stuck. It was a significant structure, consisting of a wood pile trestle approximately 590 feet long with a double-leaf bascule draw span operated with pulleys and counterweights suspended from towers. In 1889, tolls were collected from 9,636 "carriages, wagons and carts" totaling \$860.74 and a dividend of 4 percent returned to the investors. In 1902 the Dover & Eliot Street Railway incorporated and purchased rights to the bridge, widening and reinforcing it to carry streetcars. A new single-span timber queen truss bascule draw was evidently installed at that time. The line then merged with four other street railway companies forming the Portsmouth, Dover & York Street Railway, later a part of the Atlantic Shore Line Railway.⁵¹ By World War I, the Shore Line was losing money and went into receivership. The Portsmouth, Dover & York was separated out and continued in operation until 1923 when, upon failing to muster investors to extend the line over the new Portsmouth Memorial Bridge, it too went bankrupt. By 1925 the tracks were torn up and all assets liquidated.



Dover topographic map of 1893, showing the Eliot Bridge crossing the Salmon River just above its confluence with the Cochecho River.

The City of Dover assumed ownership of the bridge and by 1937 it was in such poor condition that the city was sued by a plaintiff claiming personal injury "through alleged want of repair to Eliot Bridge."⁵² Dover teamed with the New Hampshire Highway Department and the Maine State Highway Commission to completely rebuild the bridge in 1938. In 1950 the draw span was replaced with a fixed I-beam stringer span and in 1982 the entire structure was replaced with the present bridge, a 27-span steel and concrete structure, now known as Gulf Road/Dover Road over Salmon Falls River, State Bridge # Dover 182/123.

4.10 Wentworth Bridge, 1878 – 1942



Aerial view, c.1940, with the Wentworth Hotel at far right. Note the hotels swimming lagoon and dock in the foreground just south of the bridge. Courtesy Portsmouth Athenaeum.

Wentworth Bridge, also originally called Wentworth House Bridge, was built near the crossing of a ferry operating by 1643 and a toll bridge built in 1759.⁵³ In 1778 a lottery was authorized by the NH Legislature, "to complete a bridge already begun," but the law provided no additional details other than it was a toll bridge.⁵⁴ A bridge between Rye and New Castle is depicted on a 1770s map (at right).⁵⁵ The bridge evidently failed and on June 14, 1800, the Legislature granted new rights to "The Proprietors of New Castle Bridge" to build a toll bridge "over that part of the Piscataqua river called Little Harbour, from the Southwestern side of The Island of New Castle, to the public landing place in Rye, opposite said Island."⁵⁶

There is no evidence the bridge had a draw span and the law did not require one. Tolls were insufficient to carry the investment and "on account of want of travel and bad management" it fell into decay and "at length its owners took away, each one, such a portion as they thought themselves entitled to."⁵⁷ In 1821 a new corporation was chartered under the same name, "The Proprietors of New Castle Bridge," to build a bridge "from at the Northwest end of the Island of New Castle to the town of Portsmouth" (see Section 4.5).

A half-century passed before Rye and New Castle reconnected with a bridge. During the 1870s the Gilded Age of seaside homes and resort hotels took rise and Daniel E. Chase and Charles E. Campbell saw opportunity on a high point of land at the south end of New Castle Island, overlooking Little Harbor. His plan for a grand hotel and the potential for more like it was impetus for the towns of Rye and New Castle to improve roads and build a bridge to serve it. On July 3, 1872 the Legislature authorized the two towns to erect a bridge "laid out and constructed with a draw... for the reasonable and proper use of said Little Harbor river, for the navigation of vessels or rafts, or for running timber therein."⁵⁸

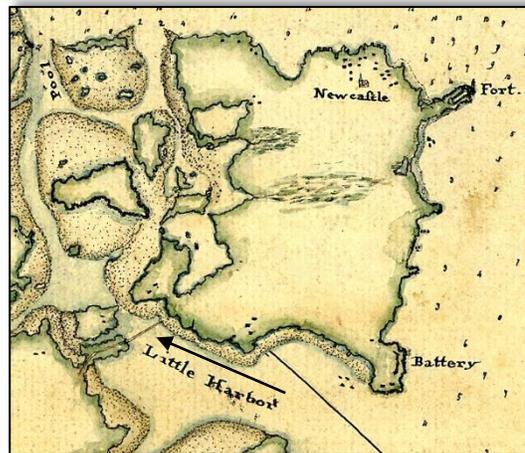


Chart of the coast of New Hampshire... dating from the 1770s depicting the first bridge to New Castle reportedly built in 1759.



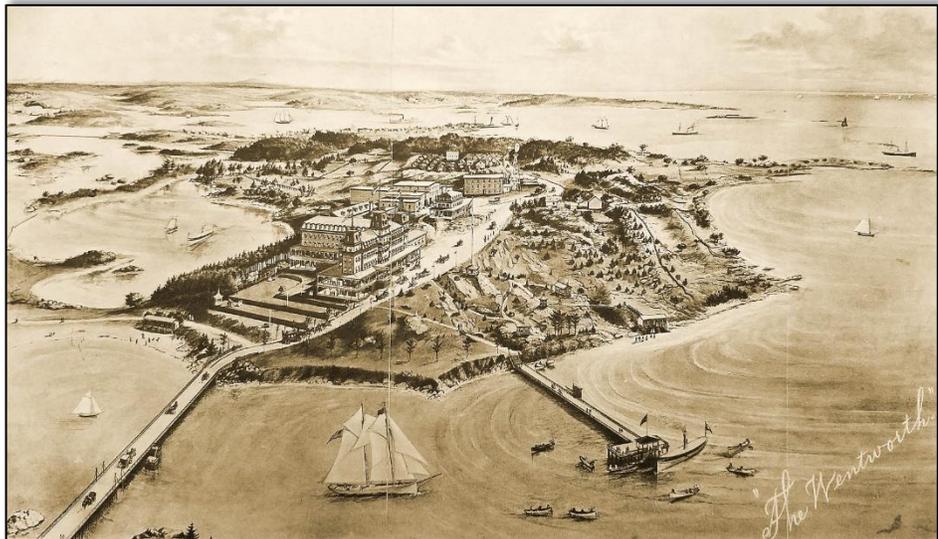
Wentworth House Bridge located on 1893 topo map. The three-section Portsmouth-New Castle Bridge spanning two islands is seen landing at the northwest corner of Newcastle Island.

The Hotel Wentworth, reputed to be the largest wooden structure on the New Hampshire coast, rose in 1874, along with the Wentworth House Bridge and Wentworth House Road, all named for the famous Wentworth family and their mansion across Little Harbor in Portsmouth. The hotel was purchased in 1879 by Frank Jones and greatly expanded. Saved from demolition in the 1990s and restored, it stands today as one of the National Trust's Historic Hotels of America.

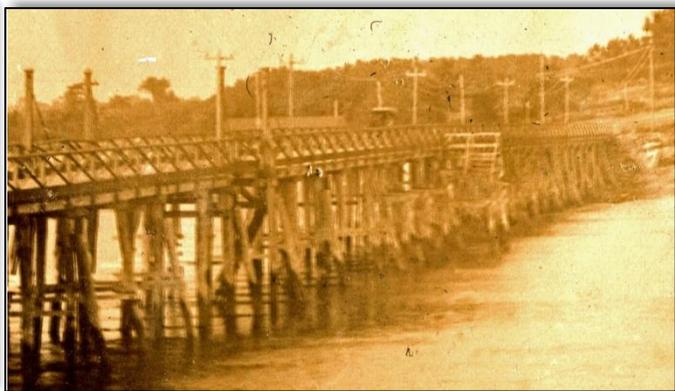
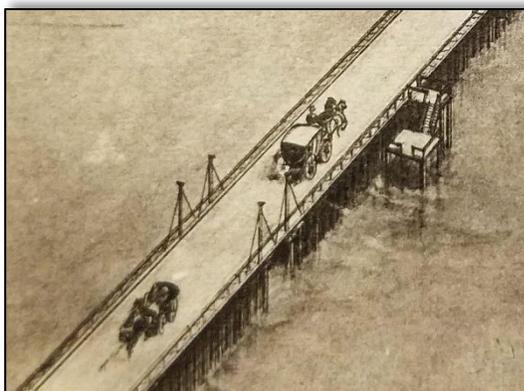


Postcard, c.1915. Courtesy of Portsmouth Athenaeum.

Little history of the Wentworth House Bridge during the 20th century was obtained. It was reportedly taken over by the state highway department in 1925. In 1940 when the draw was raised for a local resident to bring in a schooner with a 25' mast, it was reported in a newspaper as the first opening of the draw in twenty-five years. It survived until World War II when it was replaced with the Newcastle-Rye Bridge as part of the defense effort.

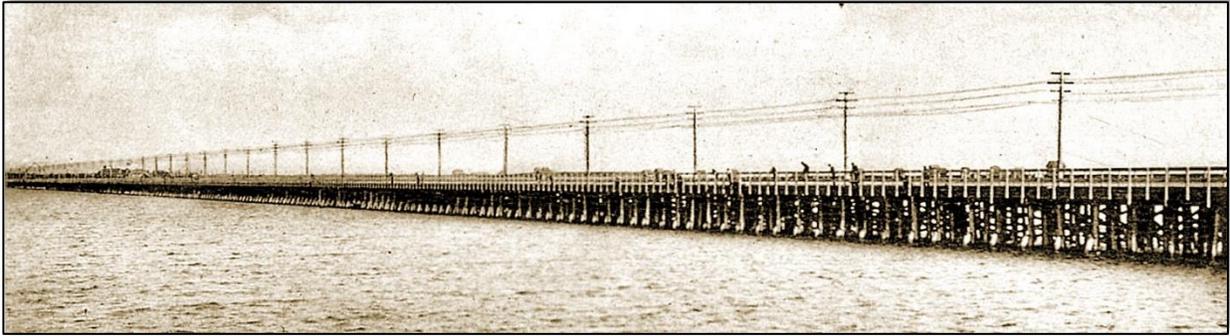


Bird's Eye View of Hotel Wentworth. In *New Castle Historic and Picturesque*, by John Albee, 1884. See detail of bridge at lower left enlarged below.

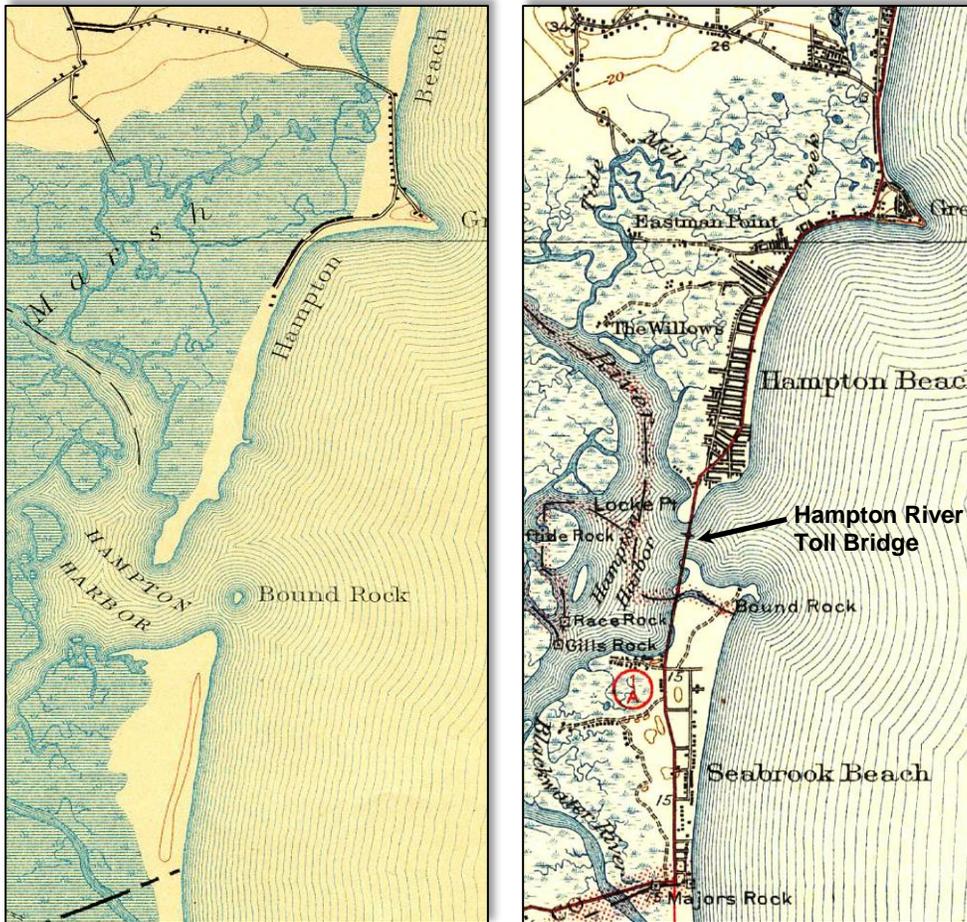


Wentworth House Bridge was a typical wood pile trestle roughly 600 feet long between stone abutments. There was about 20 feet of clearance beneath it at low tide. Based on sketches and photographs the bridge was equipped with a double-leaf hinged bascule draw manually operated with pulleys and counterweights suspended from pile towers (sketch, left, Albee, 1884; photo, right, c. 1915, courtesy of Portsmouth Athenaeum).

4.11 "Mile Long Bridge" / Hampton River Toll Bridge, 1902 – 1949



The famous "Mile Long Bridge," more officially known as Hampton Harbor Bridge or Hampton River Toll Bridge was a monumental wooden trestle bridge built in 1902 with separate travel lanes for street railway (trolley cars) and highway traffic. It opened the door to rapid development of beach front property in the towns of Hampton and Seabrook and transformed the area into a New England vacation and recreational destination. Photo, undated, courtesy of Lane Memorial Library.



The effect of the bridge on the coastal area shown by the 1895 and 1935 topo maps. Accompanying the 1902 bridge were trolley tracks and roads into areas that had neither, joining the beach areas and town centers of Seabrook and Hampton with a continuous transportation loop. The USGS resurveyed the Exeter quadrangle following the extensive filling and seawall construction completed by the state the year before that dramatically altered the shoreline.

The building of a bridge across the inlet to Hampton Harbor was a direct outgrowth of the establishment of seaside resorts at Hampton Beach and Seabrook Beach. Seaside recreation arose in Europe in the 18th century for the upper classes and was extended to the middle and working classes in the mid-19th century by the railroads that offered them affordable transportation. By the late 19th century, beach resorts such as Coney Island combined casinos and fine hotels for the rich with inexpensive food and amusements along the beach and boardwalks for the working class. The construction of electric traction in the form of subways and street car lines during the 1890s, into areas not served by the steam railroads, led to a boom in seaside resort development along New Hampshire's short but beautiful coastline.

Wallace D. Lovell, a developer from West Newton, Mass. saw opportunity along the Hampton and Seabrook coast. At the turn of the century he embarked on a remarkable program of development. He bought up shore properties on speculation and in 1898 built the Hampton Beach Casino. Meanwhile he consolidated the trolley lines in the region to form the Exeter, Hampton and Amesbury Street Railway. Then, to tie his properties together and make them more accessible by vacationers and second-home builders from the north and south, Lovell formed the Granite State Land Company to build a monumental wood trestle bridge across the mouth of Hampton Harbor. Completed in 1902, the bridge carried trolley tracks and automobile traffic as part of the state's Ocean Boulevard.⁵⁹

When Lowell first announced his plan for the bridge, many doubted the investment would pay off or that it would ever be built. When a contract was awarded to Cowles & Childs Construction of Northampton, Mass. in the spring of 1901, the *Hampton Union* noted that "The idea of a 5,000 foot boulevard bridge over a tidal river, placed for the greater part on piles, seems a stupendous undertaking even for the powerful Lowell interests, but it now seems assured as only a few days ago the contracts for building it were awarded to Boston parties."⁶⁰

The risks of building a structure across a wide inlet unprotected from driving Nor'easters and powerful tidal and longshore currents – risks



Cowles & Childs Construction Co. driving piles for the bridge in 1901. The 4,923-foot structure stood on 5,270 oak piles. It was completed in one year by three steam pile drivers. A 30-foot bascule draw spanned the river channel near the middle of the bridge. Photo courtesy of Lane Memorial Library.



Postcard showing opening of the Mile Long Bridge to trolley and pedestrians on May 14, 1902. New Hampshire Governor Chester Jordan drove the first streetcar over the structure to the cheers of some 2000 in attendance. A ceremonial banquet was held at the Whittier Hotel for dignitaries (Lane Memorial Library).



Postcard c. 1912. (Lane Memorial Library).

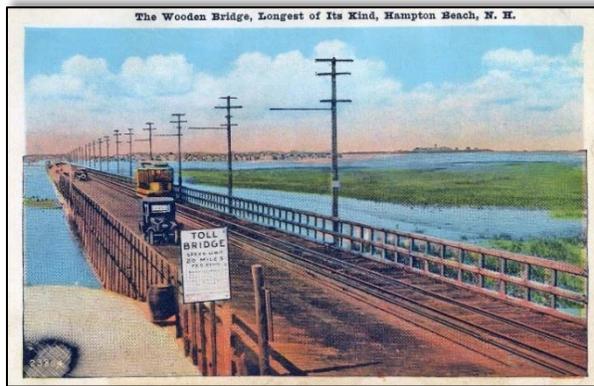
voiced by the locals but brushed aside by Lowell – were soon realized. In late December 1902, after being hammered by a series of storms, the *Portsmouth Herald* reported "parts of the big Hampton River bridge are sinking. It may be remembered that many people prophesied this before the bridge was built."⁶¹

The builders of the bridge inspected the structure and found the sand around the pilings at the south end of the bridge completely washed away, "so that a stretch of sixty feet of the bridge now rests only on the points of the piles, and the section has dropped fully eight inches."⁶²

Repairs were made and the bridge reopened in time for the 1903 beach season, but the episode marked the beginning of a costly and ongoing problem.

In 1906 undermining caused a sag of 18 inches over a distance of 300 feet and in 1911 heavy seas and river ice carried away a dozen pilings. In July 1917, heavy surf washed out the sand from a long stretch of pilings, closing the bridge to vehicles for a week of repairs in the height of the season and leaving cottagers and beachgoers to walk across. The following winter 600 feet of the weakened structure collapsed and drifted away. As the repairs were just being completed for the 1918 season, fire destroyed 125 feet of the new construction, pushing the opening to the end of June. Fires started by cigarettes tossed on the bridge and fanned by sea breezes were a constant problem. Locals and motor clubs lobbied the State to buy the bridge and make Ocean Boulevard a state highway, and the bridge owners offered it up for \$75,000, about what it originally cost to build, but it needed an estimated \$50,000 in repairs and the State refused.⁶³

In 1930 the trolley operator went bankrupt and the receivers ordered the bridge sold. After three years of deliberations and lawsuits, the State bought the bridge for \$140,000 in October 1933. The June session of



Postcard c. 1912. (Lane Memorial Library).



Toll booth at Seabrook end of bridge. The overhead timber frame supporting the lifting cables for the bascule draw span is visible in the distance. No plans or photos of the draw were located. This photo and one below taken July 1, 1940 by NHHD during inventory of the state's bridge conducted just prior to World War II (Bridge inventory card, Hampton 300/043).



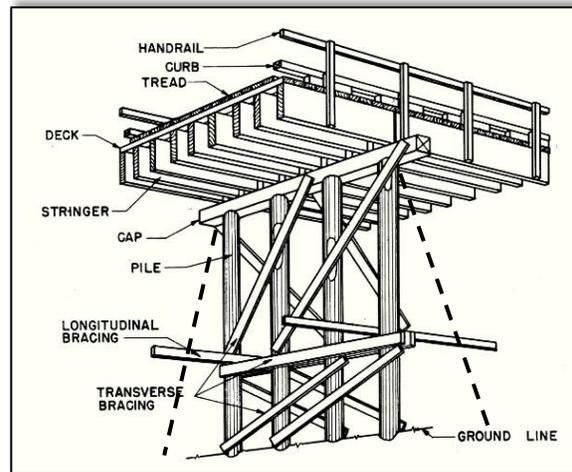
The trestle was carried on an estimated 870 timber bents. A typical bent as shown below consists of wood pilings joined with timber bracing. A heavy timber cap rests on the piles and carries the deck stringers, to which the decking, curbs and railings are attached. At each end of the bents were "batter piles" that were driven at an angle and bolted to the bent to brace against the forces of ice, boats and flotsam driven against the trestle by wind and tides.

the Legislature had unanimously approved a bill authorizing a total of \$510,000 for the purchase of the bridge and for "Emergency Construction for Coastal and Highway Protection" to include breakwaters, jetties, sea walls and other structures to stabilize the mouth of Hampton river and prevent erosion of the adjacent beaches, the state's coastal highway, the bridge and its approaches."⁶⁴ The growing economic importance of the bridge and this stretch of coastline to the state was apparent as was the growing threat of the sea to its usefulness.

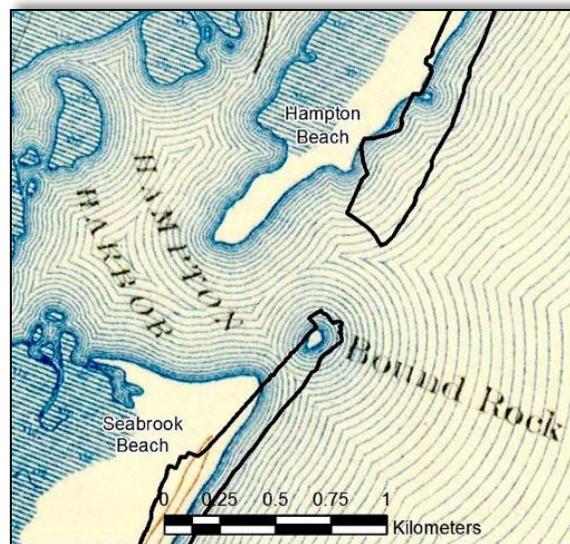
Bridge and shore improvements got underway in 1934 including a concrete seawall at Hampton Beach, stone jetties along the inlet and hydraulic dredging to fill behind the jetties to create land for park use, to deepen the channel, and to create a boat basin about a quarter-mile square as a safe harbor with docking facilities. Work on the bridge in late 1934 included lengthening the draw span by ten feet on the Hampton side to increase the opening width for boats from 30 to 40 feet. A bent of pilings was removed and a new steel I-beam lift span and bearings were installed.⁶⁵

In March 1935 the *Portsmouth Herald* reported at length about the positive effects the coastal improvements were already having on the coastline. The Hampton River, now channeled between two walls of granite 1200 feet apart was scouring the channel deeper. The granite walls, extending into the ocean as jetties, were already trapping sand and increasing the width of the beaches.

In 1936 a new mechanical system and rigging for opening the draw was installed that reduced the opening and closing time from 50 minutes to 8 minutes but traffic jams continued to plague the bridge. A four lane bridge was needed and the wood trestle was at the end of its life. The New Hampshire Highway Department announced in 1938 a new bridge would soon be built, but World War II intervened and it would be another 10 years before construction was underway. The new steel and concrete structure, ultimately named the Neil R. Underwood Memorial Bridge in memory of a World War II Army Air Force flyer from Hampton, opened in 1949. See Section 4.17 for that story.



Typical timber pile trestle construction showing a "bent" consisting of four pilings cross braced and capped with a heavy timber on which the deck stringers rest. Not shown are batter piles driven at an angle to brace the bent against side loads from wind, current and ice, represented by the dashed lines.



Shoreline today (black outline) compared to 1894 shoreline (Olson and Chormann, 2017).

4.12 Piscataqua River Bridge / Memorial Bridge, 1923 – 2013

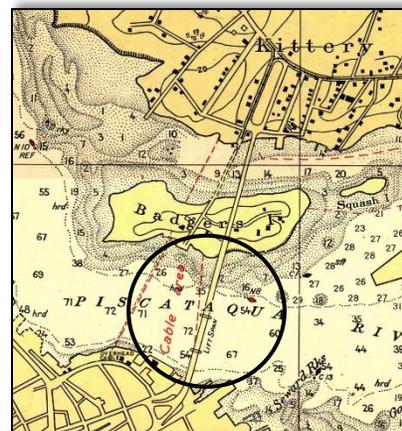


First known as the Piscataqua River Bridge, then named Memorial Bridge in honor of those who served in World War I. It was the state's first vertical lift bridge when it opened on August 17, 1923. The monumental structure formed an important link in the new US Route 1 coastal highway from Maine to Florida. By the late 1930s four million vehicles were crossing the bridge annually. Photo taken in 1940 by the NH Highway Department.

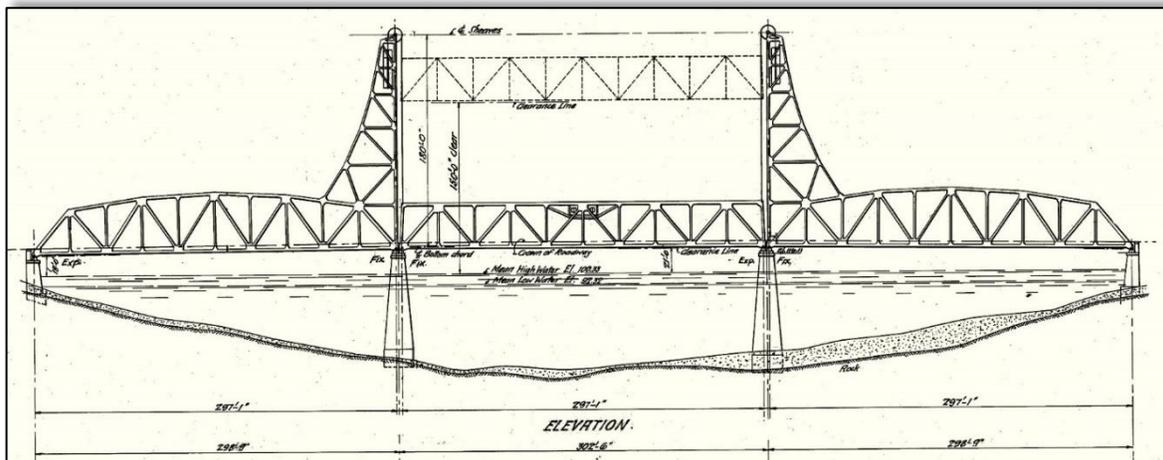
Memorial Bridge stood for 90 years as one of the state's most important visual, cultural and engineering landmarks. With two steel truss towers 210' high, it dominated Portsmouth's landscape and strengthened the city's social and economic bonds to Kittery and the Naval Shipyard. Designed by J.A.L. Waddell, the father of the modern vertical lift bridge, it was the longest lift span (297') in the country and the first major lift bridge on the east coast.

The bridge entered the new millennium as one of the oldest operating lift bridges in the country but was found critically weakened by corrosion. Efforts to save the bridge failed to overcome the huge rehabilitation costs involved and in 2011 it was permanently closed. Replacement plans were quickly drawn and approved and construction of the new bridge began in 2012.

Visit the NH Public Radio website, *Timeline: History of the Memorial Bridge and Events Leading to its Replacement*, by scanning the QR code at right:



USC&GS Chart 329, Portsmouth Harbor, 1945.



Elevation drawing from original plans prepared by J.A.L. Waddell Consulting Engineer, New York City, 1920.

On August 8, 2013 the new Memorial Bridge opened at a cost of \$90 million, a highly innovative design that mimicked the historic outlines of the original bridge. It was the first gussetless truss in the U.S. and incorporated many state-of-the-art engineering features including cold bending of steel, splicing assembly and a metalized zinc coating to prevent corrosion for up to 50 years. Visit the NHDOT *Memorial Bridge Replacement* website, by scanning the QR code at right:



New Memorial Bridge, opened 2013. Photos above and below taken March 30, 2018 by Jerry Zoller, New Hampshire Department of Transportation.



4.13 Newfields – Stratham Swing Bridge, 1926 - 2000



Newfields-Stratham Swing Bridge over Squamscott River. Photo 1941, New Hampshire Highway Department.

The Newfields-Stratham Swing Bridge was built in 1926 to replace the Stratham Bridge, a 19th century timber trestle bridge with a bascule draw that could not meet the demands of modern car and truck traffic. The swing span was of the plate-girder center-bearing type, the only highway bridge of its kind in New Hampshire. The Portsmouth & Concord Railroad "Great Bay Bridge," a mile downstream, and the Portsmouth & Dover Railroad "Dover Point Bridge" were also swing bridges.

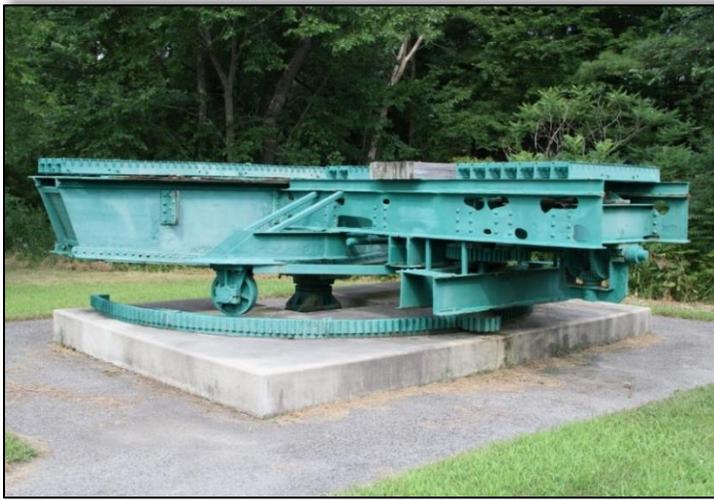
The Newfields-Stratham swing span was designed and built by Phoenix Bridge Company of Pennsylvania, one of the leading bridge builders of the late 19th and early 20th centuries. The manually operated swing mechanism was designed and manufactured by the Earle Gear and Machine Company of Philadelphia.

In 1933, the Boston and Maine Railroad discontinued operation of the former Portsmouth & Concord Railroad Great Bay swing bridge and converted it to a fixed span. This action ended navigation on the Squamscott River by tall vessels, and made further operation of Newfields-Stratham Swing Bridge unnecessary. In 1953 the swing span was permanently welded shut and remained in that state until August, 2000 when construction on a new bridge alongside it began. The new bridge is upstream from the old one and measures 400 feet long with a 5-foot sidewalk for walking and biking. The \$1.8 million bridge was part of a \$5 million improvement project of Routes 108 and 87.

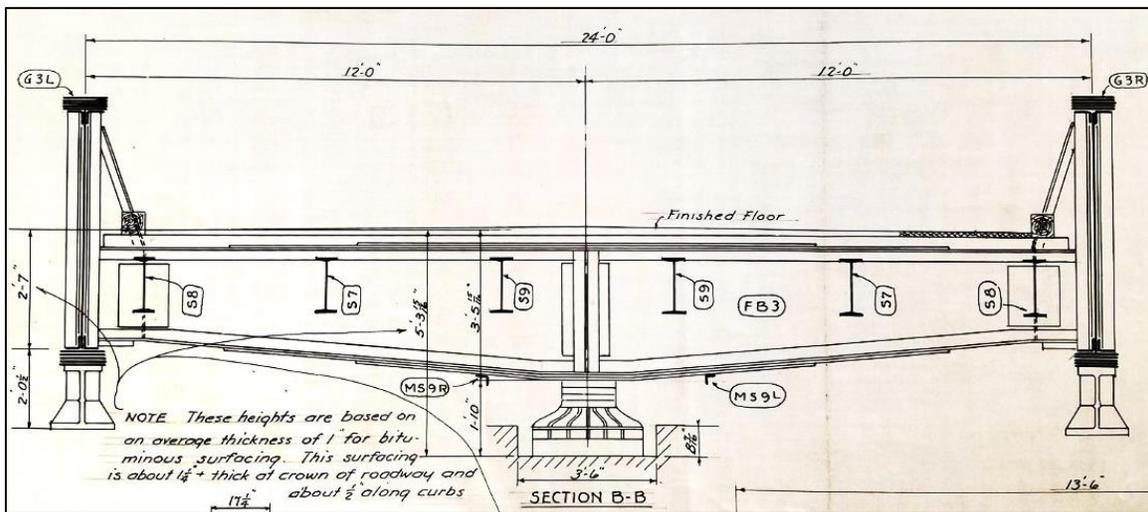
The bridge was recorded to Historic American Engineering Record standards in January 2000.⁶⁶



Location of Newfields-Stratham Swing Bridge, carrying NH Route 108 over the Squamscott River, shown on 1941 topographic map.



The bridge swing mechanism, called the capstan, consisted of a spur reduction gear-set and a rack-and-pinion gear-set to rotate the span. The bridge was opened manually by the bridge tender who inserted a long bar through a hole in the roadway and into a socket on the capstan and then walked in a large circle to turn the gears. The mechanism has been preserved in a park adjacent to the new bridge with signage explaining the history of the bridge and crossing.



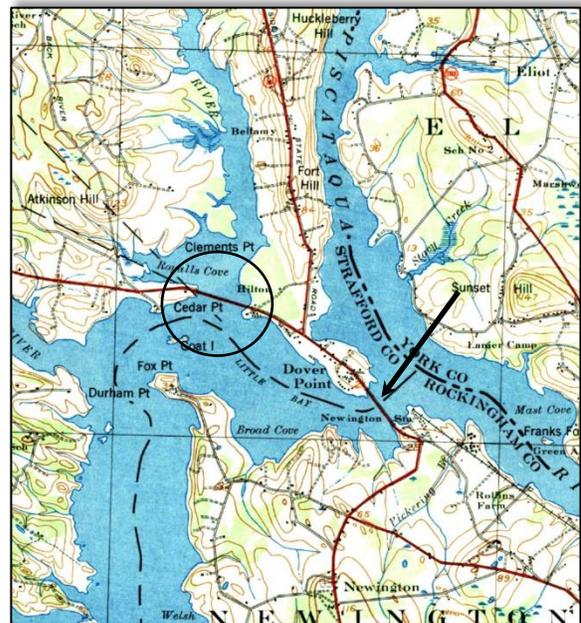
Clip from original plans drawn by Phoenix Bridge Company in August 1925, showing cross section through the heavily reinforced and tapered center floor beam of the swing span. Called the loading girder, it distributes the entire dead load of the swing span when it is open from the main girders (vertical members at each end of the loading girder) to the center pivot bearing. The center bearing consists of a double-convex hardened phosphor-bronze disk, 13" in diameter, mounted between two hardened-steel concave disks also 13" in diameter. The bearing faces of the three disks are ground to a 30" radius. The bearing disks are mounted in a cast steel pedestal, 36" in diameter, shown in the drawing at bottom center. The upper section of the pedestal bolts to the loading girders of the swing span; the bottom section of the pedestal bolts directly to the pivot pier in an 8"-deep well cast into the concrete. Portions of this assembly were saved and displayed as noted in the photo above.

4.14 Bellamy River Bridge / Col. Alexander Scammell Memorial Bridge, 1935 – 1998

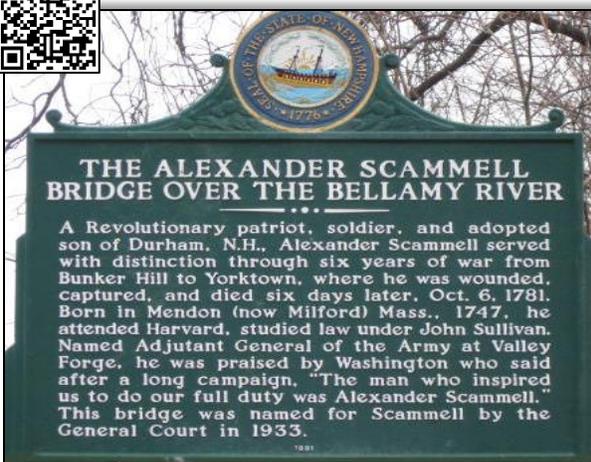


The west approach of Scammell Bridge in July 1940 with original decorative concrete railings and lamp posts. The draw span was of the trunnion bascule type with a massive overhead concrete counter weight seen above. A trunnion is a stationary horizontal pivot like a hinge around which the draw rises and the counterweight falls. Note the approach guardrails consisting of three lines of "metal tape" or "metal ribbon" on round wood posts painted white. Metal tape, consisting of galvanized metal wires woven into a flat band came into use in the 1930s and was considered an improvement over standard 3/4" wire cable guardrails.

The Colonel Alexander Scammell Bridge was officially called the Bellamy River Bridge prior to being renamed for the Revolutionary War hero who served in the First New Hampshire Regiment. It was built by the NH Toll Bridge Commission as part of a large Depression-era project funded by the Public Works Administration to replace the Boston & Maine RR combined highway-railroad bridge between Dover Point and Newington. The project also included construction of State Route 4 and the General Sullivan Bridge over Little Bay. When it opened in 1935, the Bellamy River Bridge reestablished the direct link to the First NH Turnpike in Dover that was lost when the Piscataqua Bridge collapsed in 1855.



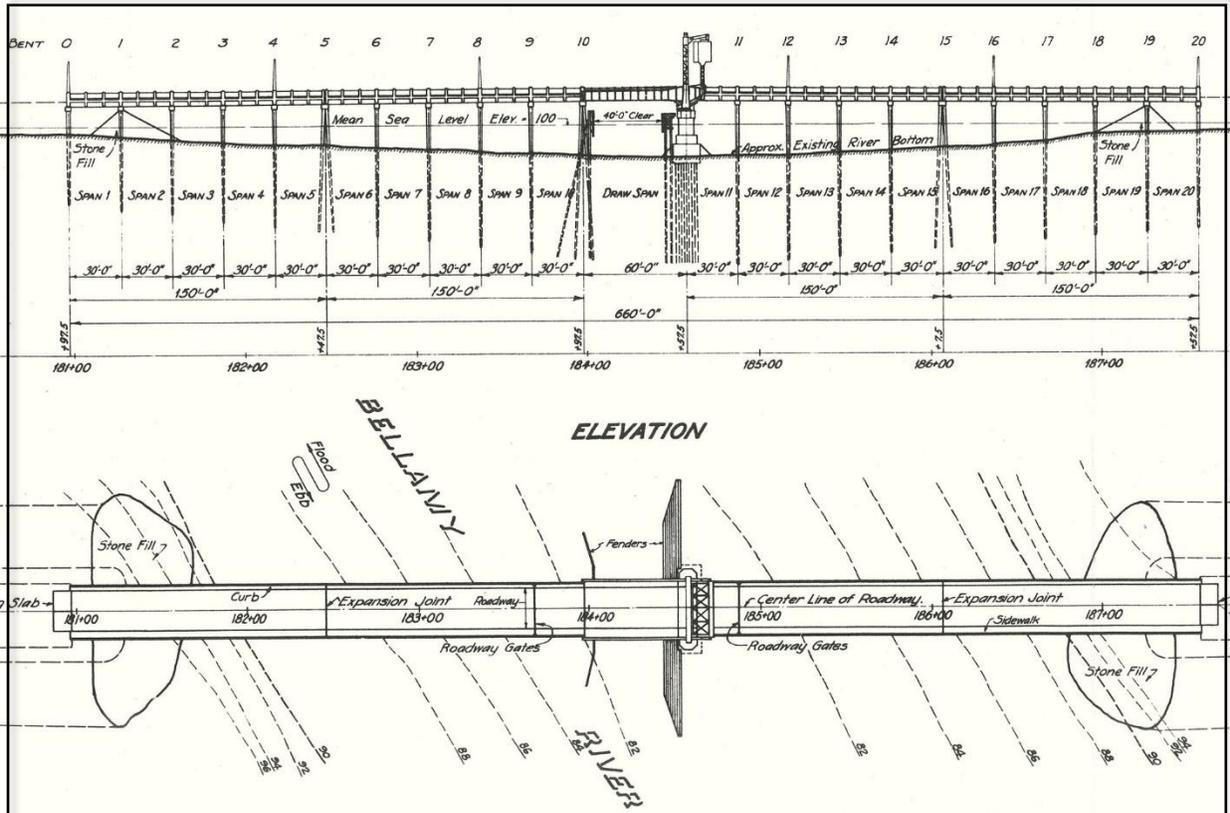
Scammell Bridge (circled) on 1941 topo map carrying the new state Route 4 over Bellamy River. Arrow marks the high-level General Sullivan Bridge, also built as part of the huge project funded under National Industrial Recovery Act (NRA).



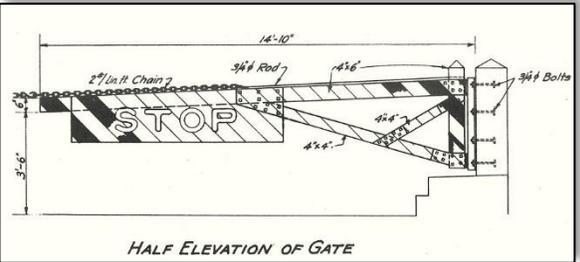
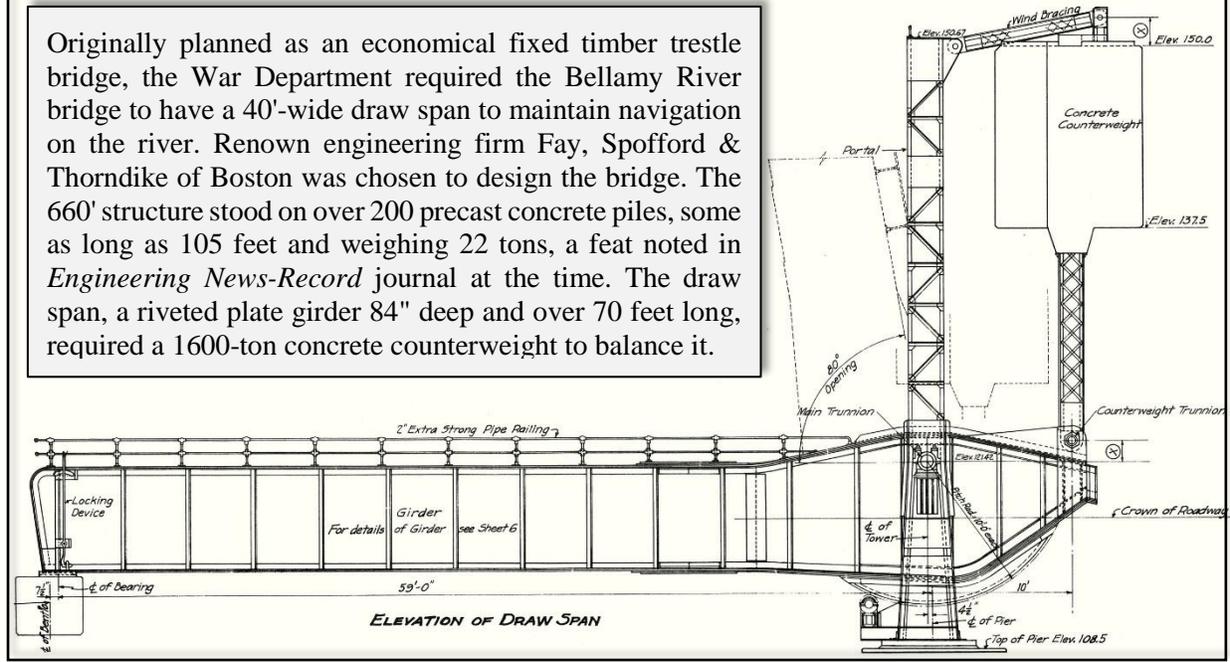
State historical marker at the west end of the bridge. To see all state markers online scan QR code above or go to www.nh.gov/nhdhr/markers/



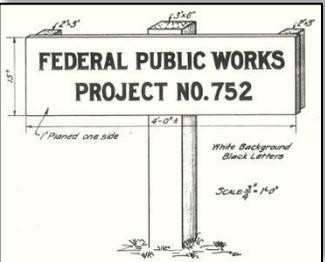
Poster erected by construction contractors to show compliance with NRA regulations. NRA postage stamp issued 1933.



Originally planned as an economical fixed timber trestle bridge, the War Department required the Bellamy River bridge to have a 40'-wide draw span to maintain navigation on the river. Renown engineering firm Fay, Spofford & Thorndike of Boston was chosen to design the bridge. The 660' structure stood on over 200 precast concrete piles, some as long as 105 feet and weighing 22 tons, a feat noted in *Engineering News-Record* journal at the time. The draw span, a riveted plate girder 84" deep and over 70 feet long, required a 1600-ton concrete counterweight to balance it.



Original gate protecting the opening when the draw was raised.



Sign erected at the bridge construction site.

By the mid-1980s, after 50 years of service in a harsh saltwater environment, the concrete pilings, piers and T-beams supporting Scammell Bridge were crumbling and beyond practical repair. A draw span was no longer needed so a fixed deck-girder bridge with 15 feet of clearance was approved. In 1994, prior to the replacement of the bridge, a committee of staff members of the NH Department of Transportation, State Historic Preservation Office and Federal Highway Administration, found the 1935 bridge eligible for listing in the National Register of Historic Places as one of the last three surviving bascule lift bridges in the state.

To mitigate the loss of the historic bridge it was documented to the standards of the Historic American Engineering Record (HAER) and entered into that collection in the Library of Congress. To access the full documentation online, scan the QR code below or go to www.loc.gov/pictures/item/nh0295/.



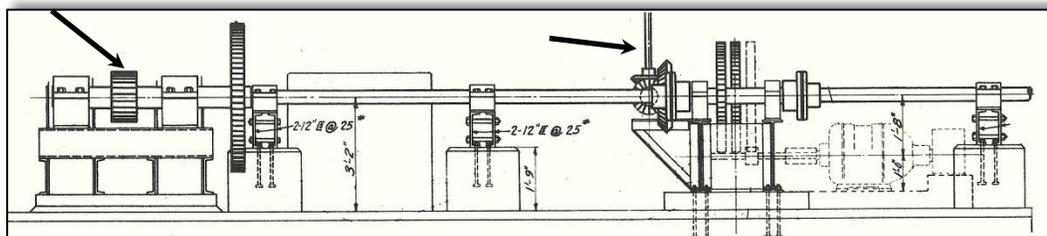
HAER photos by Charley Frieberg, 1996.

Above: Counterweight, draw span and fenders.



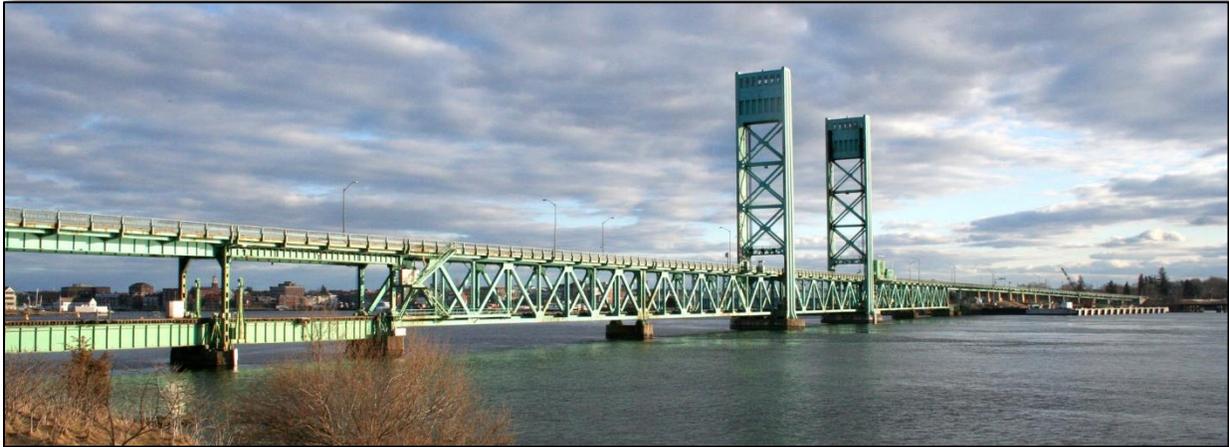
Left: Concrete T-beams and pier; rack gear on end of lift span.

Below: Underside of lift span, showing lift gear machinery.



Elevation of lift reduction-gear machinery from original plans. Arrow at far left points to pinion gear that drove the rack gear on the end of lift span to open and close it. Vertical drive shaft (2nd arrow) manually operated bridge until optional electric motor (dashed lines) was installed.

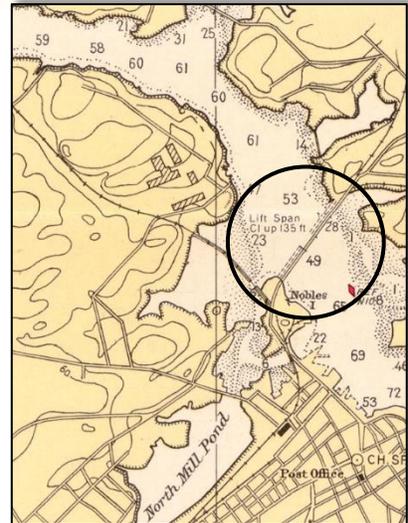
4.15 Interstate Bridge / Sarah Mildred Long Bridge, 1940 – 2018 –



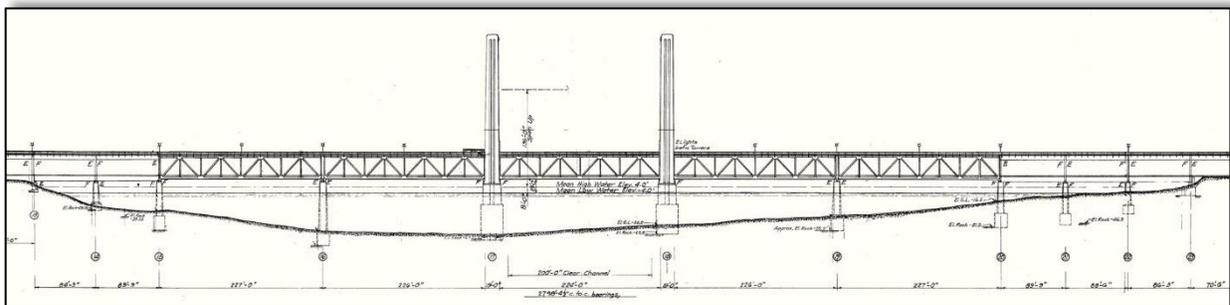
Officially known as the Interstate Bridge Authority Piscataqua River Bridge and referred to simply as the Interstate Bridge until 1987 when it was renamed in honor of Sarah Mildred Long, a 50-year employee of the Authority. In addition to the advanced vertical lift span carried on towers over the main channel, the lower level carrying the Boston & Maine Railroad was later equipped with an uncommon retractile draw, partly represented by the two green plate-girder spans visible at the lower left of the photo. Photo from Maine shore looking south, 2007, by R. M. Casella.

The "SML Bridge" as many engineers refer to it, replaced the Boston & Maine Railroad's Piscataqua River Bridge, a much repaired and altered combined highway and railroad bridge that by 1938 amounted to an obsolete hodgepodge of wooden trestle, truss and draw spans (see Sections 4.4 and 4.6). The bridge and its associated U.S. Route 1 Bypass highway around Portsmouth and Kittery was the largest project of the Public Works Administration in New England.

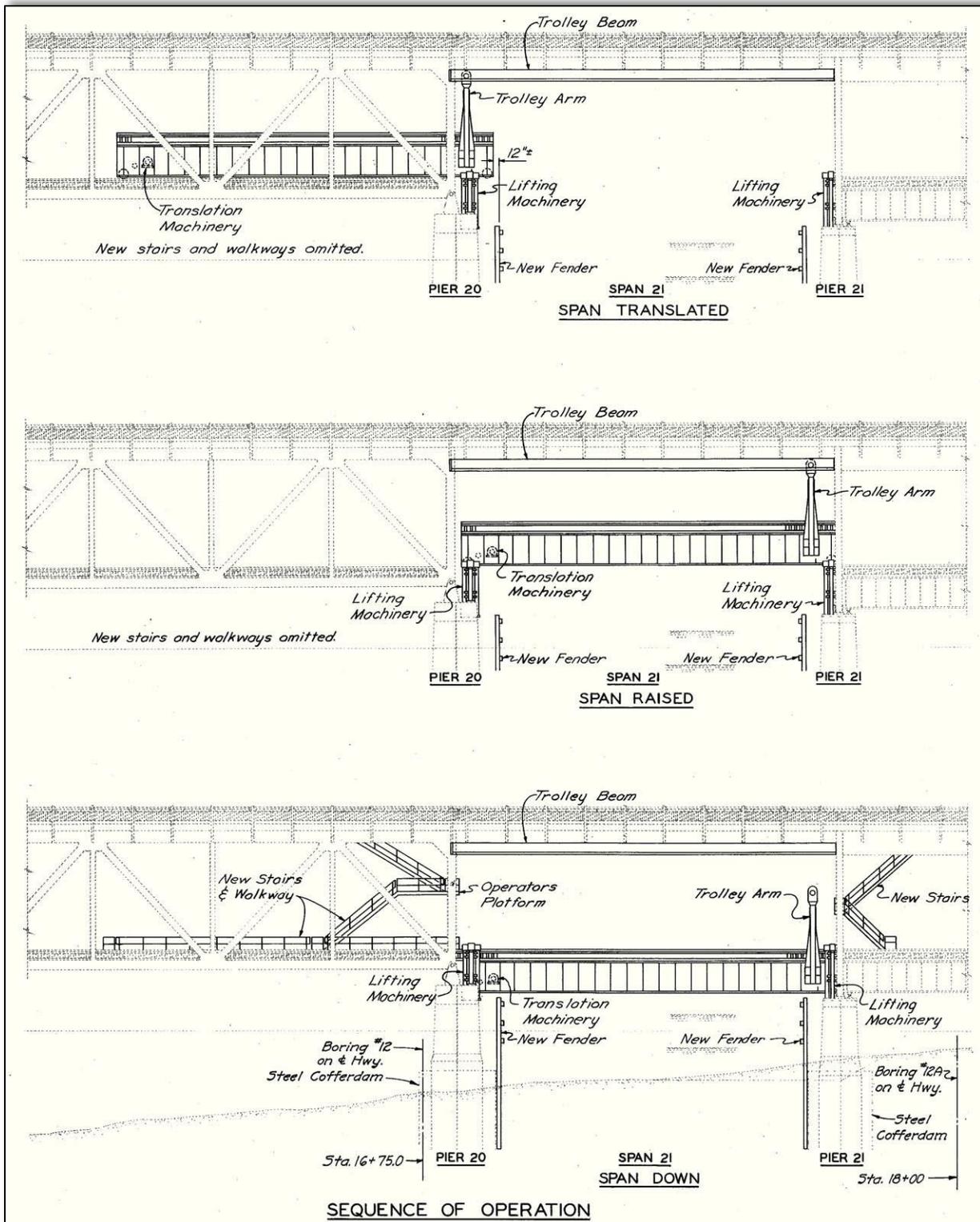
The definitive history of the need for the bridge and its construction is *The Sarah Mildred Long Bridge* by Woodard D. Openo, 1988. The SML Bridge was replaced with a new vertical lift bridge in 2018. To mitigate the loss of the historic bridge it was documented to the standards of the Historic American Engineering Record (HAER) and entered into that collection in the Library of Congress. To access the documentation online, scan the QR code or go to <https://www.loc.gov/item/nh0304/>



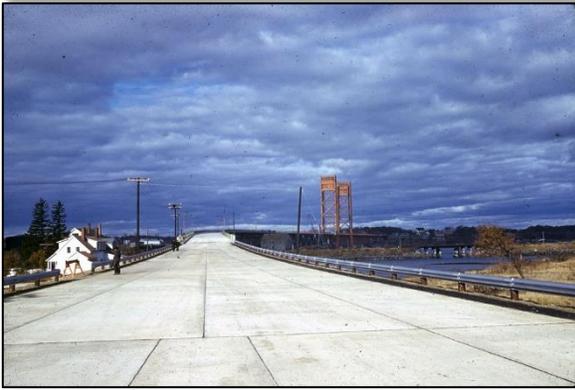
USC&GS Chart 229, Portsmouth to Dover and Exeter, 1944.



Elevation drawing from original plans prepared in 1938 by Harrington & Cortelyou, Consulting Engineers, Kansas City.



By the 1960s traffic congestion on US 1 had reached unacceptable proportions during the summer and a clever means to reduce the problem was devised. A new channel for small boats would be dredged at the east end of the bridge and a draw span added at the lower railroad level between Piers 20 and 21. Traffic congestion would be reduced by eliminating the need to raise the main lift for small craft. A retractile draw was designed whereby the draw span was hoisted vertically and then pulled back over the adjacent fixed span as shown in the engineering drawing above by Harrington & Cortelyou, 1965. A rare type, only one other retractile draw is known to have been built in the state on the Piscataqua Bridge in 1794.



Previously unseen photos of the opening celebration of the Interstate Bridge on November 8, 1940. These were taken by an unknown member of the NH Highway Department using the newly introduced Kodachrome reversal film. Discovered in the NHDOT slide collection, the slides were highly underexposed, so dark that some appeared to hold no image – a common trip-up for first time users of the film due to its narrow exposure latitude. The slides were scanned at high resolution and then digitally edited to restore the images. No notes accompanied the slides.

In 2013 the design process for a new Sarah Mildred Long Bridge began and multiple concepts were presented in public meetings. Built on a new alignment with a higher channel clearance – 56' versus 14' – reduced openings by 68 percent. The mostly concrete structure opened March 30, 2018 with a planned service life of 100 years. Extensive information on the design and construction is available online by following the many links at the project website: www.maine.gov/mdot/sml/renditions/ (QR code at right)
Also see https://en.wikipedia.org/wiki/Sarah_Mildred_Long_Bridge



Photos taken 3/30/2018 by Jerry Zoller, New Hampshire Department of Transportation.

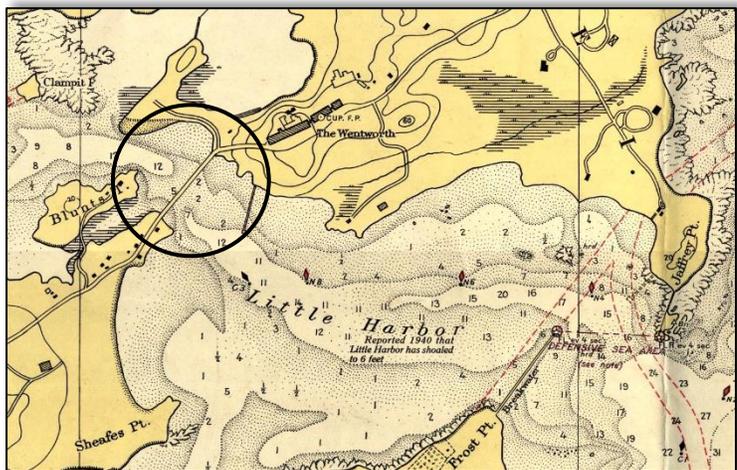


4.16 New Castle – Rye Bridge, 1942 –

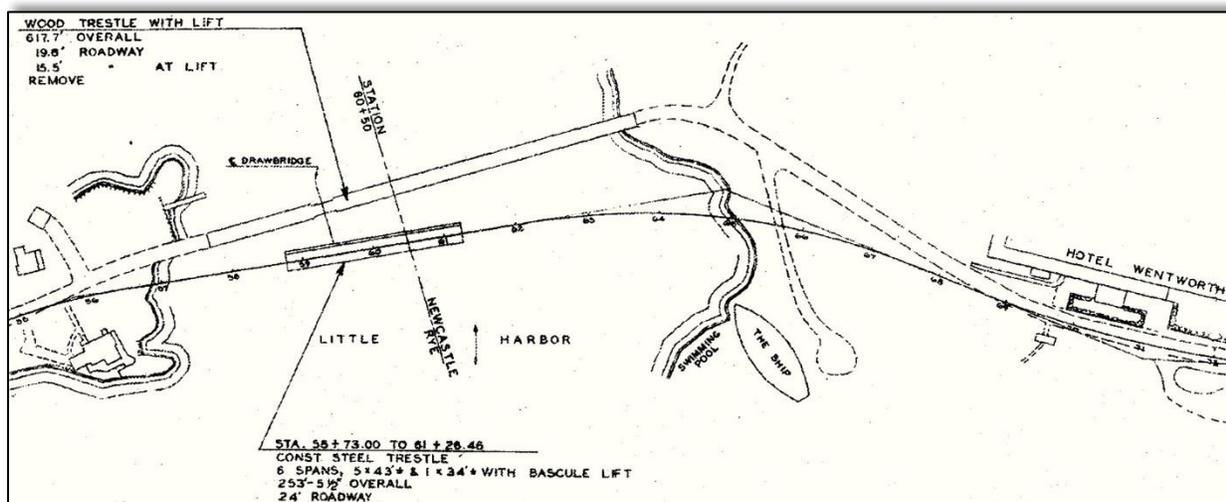


Aerial view of New Castle-Rye Bridge c. 2010, original source unknown.

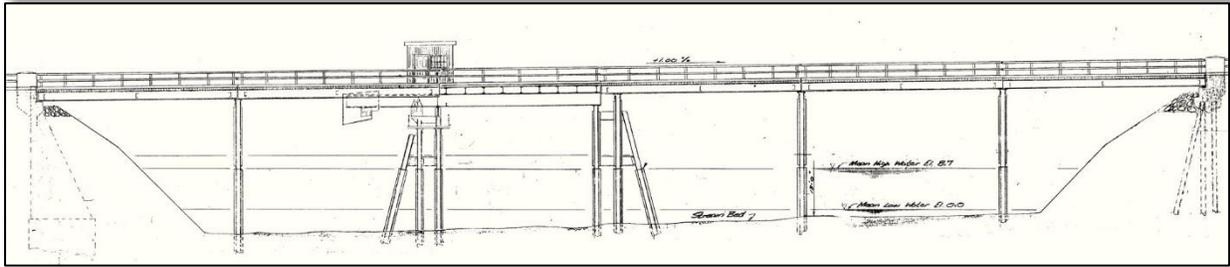
In 1941 and 1942 the two bridges accessing New Castle Island, New Castle Bridge (Section 4.5) and Wentworth Bridge (Section 4.10) were replaced under a World War II coastal defense program known as the Portsmouth Harbor Defense Area.⁶⁷ The purpose of the bridge work was to increase their capacity to carry heavy trucks loaded with building materials and military supplies supporting military operations on the island at Fort Stark, Fort Constitution and Camp Langdon. The wood trestles of the Portsmouth-Newcastle Bridge were completely rebuilt to carry 10-ton trucks; the Wentworth Bridge was completely replaced with solid causeway approaches and a steel pile bridge to carry 20-ton trucks.



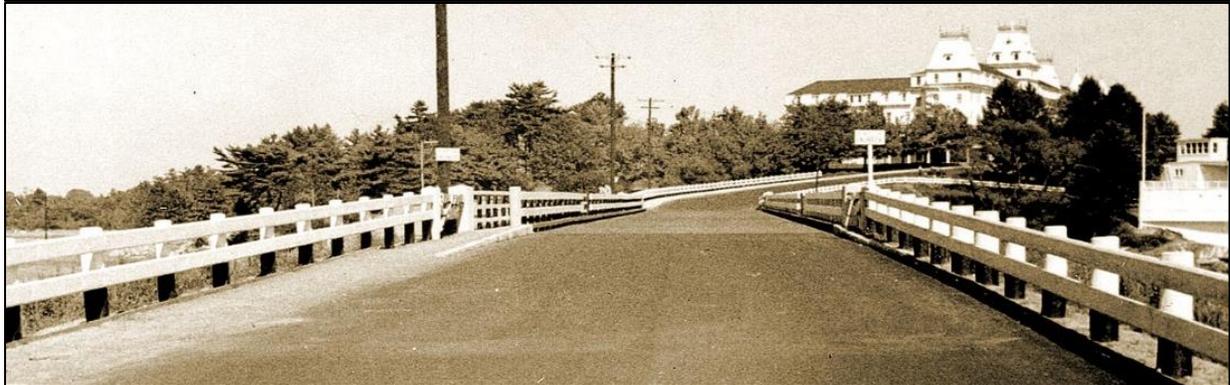
Newcastle-Rye Bridge located on USC&GS Chart 329, *Portsmouth Harbor*, 1945.



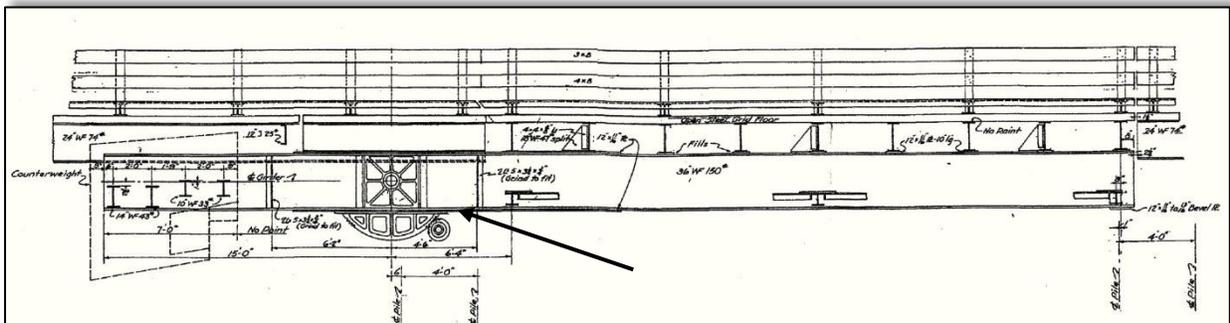
Newcastle-Rye Bridge was built on a new alignment south of the existing Wentworth Bridge which was later dismantled. The old bridge is noted as 617.7' long overall with a 19.6' roadway; the new bridge is 6 spans, 253'-5" long overall with a 24' roadway. Long filled approaches at each end of the new bridge account for the great difference in length. Clip from original plan dated December 31, 1941.



Plan clip from 1974 decking replacement and other repairs. During an underwater inspection in 1957 many of the steel piles supporting the bridge were found almost completely rotted off at the mudline. A 4-ton limit was immediately imposed and the piles encased in concrete filled steel jackets.



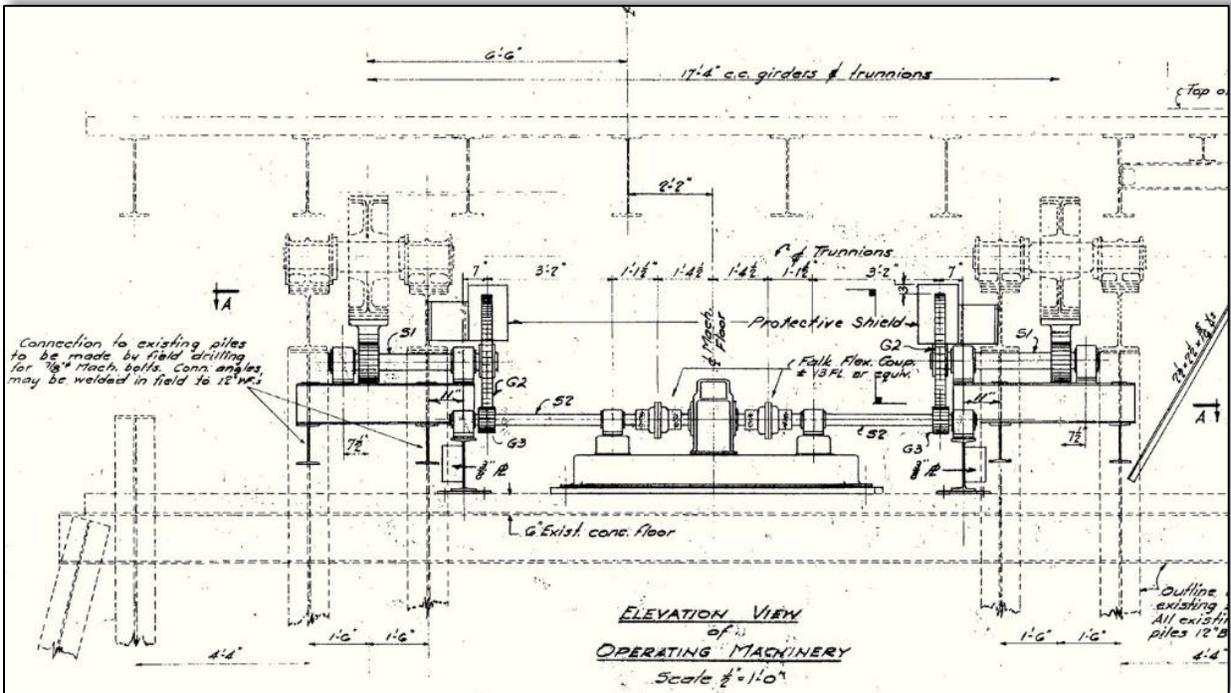
Photos of the Newcastle-Rye Bridge taken by the NHHD in 1943 shortly after completion. Top: Note the long elevated solid-fill approach causeways armored with riprap that knocked roughly 400 feet off the length of the old bridge. Bottom: Due to financial constraints during WWII, the bascule lift was not initially equipped with operating machinery or an operator's house. Those features were finally added in 1962.



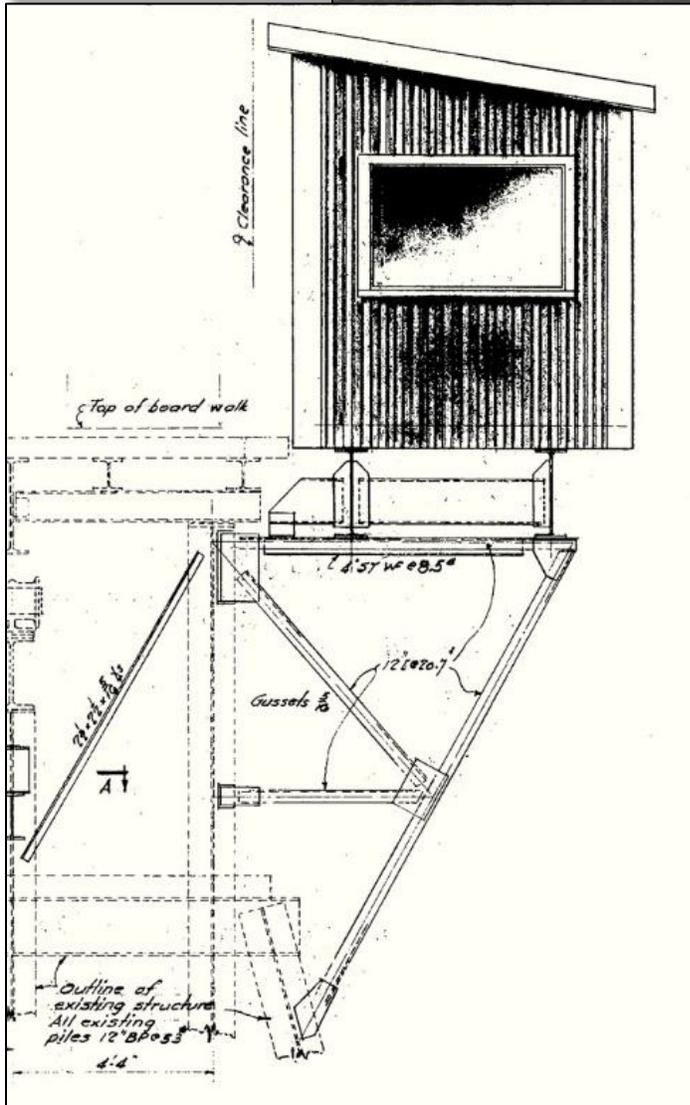
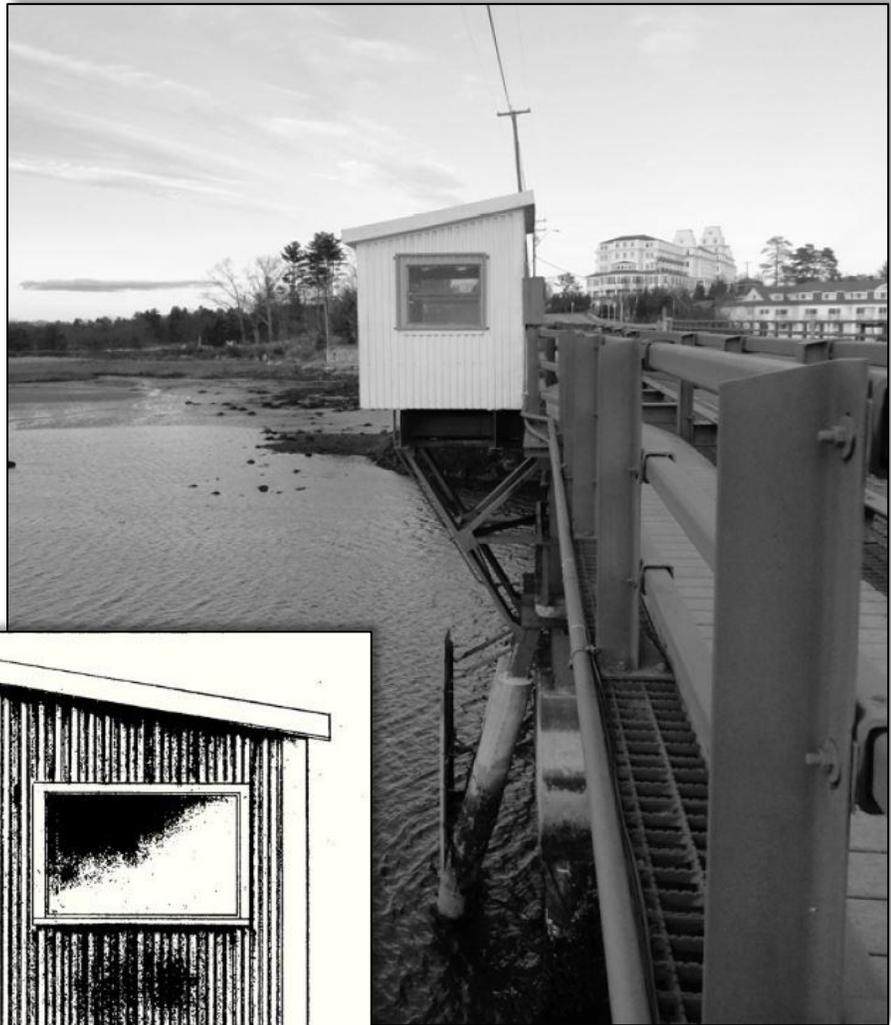
The bascule lift span as originally designed in 1941. Arrow points to rack gear and manual operating machinery that was deemed too expensive and dropped from the contract. Only the trunnion, its bearings and counterweight were installed so that the bridge could be "raised if required" but no record that it was ever opened or how it was to be done was located. Electrically operated gears and lift machinery was finally installed in 1962.



View of open bascule span, bascule pier, machinery cabinet and underside of deck. Note concrete encasement of steel H-pilings done and 1957 with later maintenance. Photo by Walter Wheeler from NHDHR Inventory Form NWC0007.



Clip from original 1962 plans for adding bascule lift operating machinery, as designed by Harold E. Langley and Robert J. Prowse. Rack and pinion gears, a reduction gear transmission and two electric motors plus associated shafting, mounts and electrical controls were installed in 1962.



A small operator's house was also added in 1962 along with the lift operating machinery. It is roughly 8' square with a corrugated metal roof and siding. Photo above by Walter Wheeler from NHDHR Inventory Form NWC0007.

The house is supported on a triangular structural steel frame welded to the outside pilings of the lift pier, as shown on the clip from the original 1962 plans.

4.17 Hampton Harbor Bridge / Neil R. Underwood Memorial Bridge, 1949 –

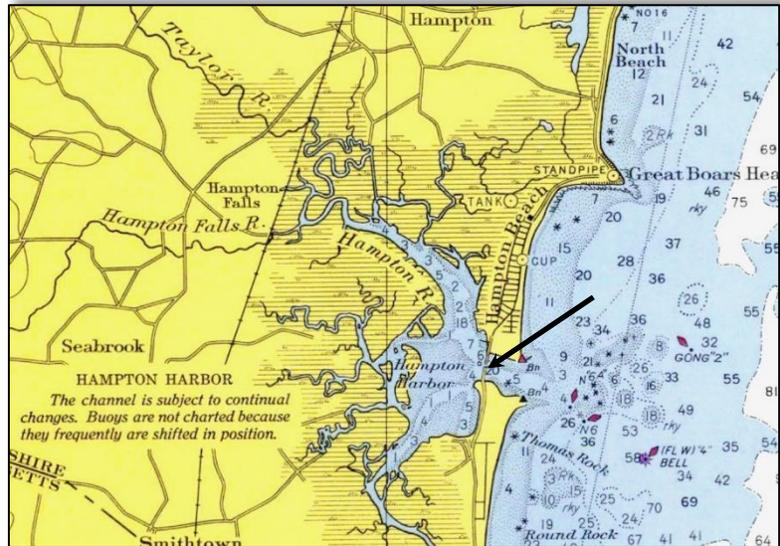


Photo 2017, courtesy of Hoyle, Tanner & Associates, Inc.

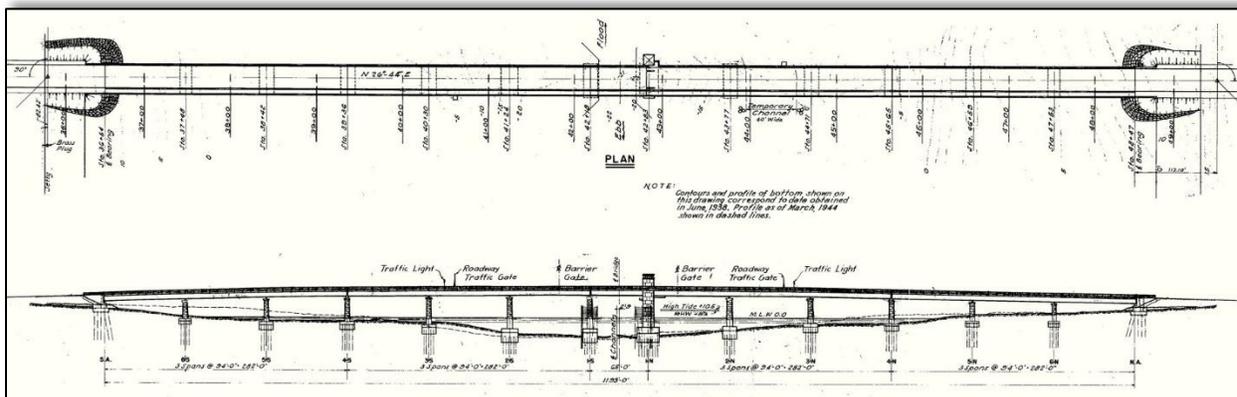
The original engineering drawings for the Neil R. Underwood Memorial Bridge, prepared in early 1946, show the bridge was then known as the Hampton Harbor Bridge.⁶⁸ In 1953, four years after its completion, the New Hampshire Legislature renamed the bridge, which they called the Hampton River Toll Bridge, in memory of Underwood, a Lieutenant in the United States 12th Army Air Force formerly from Hampton. Lieut. Underwood lost his life in the Mediterranean area on August 17, 1944.⁶⁹

The roughly 1200-foot long steel and concrete Underwood Bridge was built in 1949 to replace the famous "Mile Long Bridge," a monumental but obsolete wooden trestle completed in 1902 – also

variously referred to as Hampton Harbor Bridge or Hampton River Toll Bridge (Section 4.11). The trestle was claimed as the longest bridge in the world and perhaps it was, briefly, by some measure. There is no doubt however, that it forever transformed the towns of Hampton and Seabrook by joining their prime ocean waterfront property into a continuous strip of valuable and joyous vacationland.



U.S. Coast & Geodetic Survey Map, "Portsmouth to Cape Ann," 1958. Despite over 100 years of efforts to control the erosion and sedimentation processes around Hampton Harbor with seawalls, jetties and dredging, it remains an unpredictable problem for mariners and the bridge.



Drawings were prepared in March 1946 by the engineering firm Parsons, Klapp, Brinkerhoff & Douglas of New York. There are 12 fixed deck-girder spans of 94' and a trunnion bascule span of 65' providing an open channel 40' wide.

As discussed in Section 4.11, the State purchased the Mile Long Bridge in 1933 and in 1934 completed extensive improvements to control erosion near Hampton inlet and stabilize the bridge and its approaches. Repairs to keep the aging trestle in service were also made including a new draw span that increased the channel width from 30 to 40 feet. Plans were soon afoot at the NH Highway Department to replace the bridge entirely.⁷⁰

In August 1938 the State announced that a new four-lane steel and concrete bridge 1,200' long would replace the "Mile Bridge." Gravel approach causeways, 1600' at the north end and 1000' at the south end would greatly reduce the bridge structure length and cost. A grant from the Public Works Administration to cover 45 percent of the estimated \$581,571 cost was approved but lost due to a failure of the state to approve its share. State and federal funding was approved in 1941 and work commenced with filling the approaches but the onset of World War II brought all bridge work requiring steel and concrete to a halt.⁷¹

With the future of the project uncertain, it was decided to connect the partly completed approach at the Seabrook end with the old bridge and disassemble the 600-foot bypassed section. The salvaged timbers would be used to patch up the remaining trestle and squeeze a few more years of service out of it.

In December 1945 the project was revived and quickly approved by the War Department with minor changes. New plans were drawn with deeper pier foundations and slightly greater clearance under the draw span when closed. Construction began in March 1947 and stretched 33 months, close to a year behind schedule due to the backlog of structural steel orders following the war.

December 15, 1949 the bridge was opened without fanfare. The *Portsmouth Herald* reported, "There will be no fancy ceremonies, speeches or ribbon cutting when the new \$1,461,138 bridge opens. Toll house attendants will just open the cash registers and start taking in the 15 cent tolls at about 2 pm, State Highway Commissioner Frank D. Merrill said today. Merrill explained that the possibility of a storm, or at least cold weather at this time of the year made it inadvisable to hold ceremonies." Merrill was one of the highway department's state's most distinguished commissioners. As a WWII Army general he led "Merrill's Marauders," a special-forces team that conducted long-range penetration missions behind Japanese lines during the Burma Campaign.⁷²



Construction of gravel filled approach causeways for the Underwood Bridge on the seaward side of the Mile Long Bridge, visible in background, in the fall of 1947 (Courtesy Lane Memorial Library).



Construction of reinforced concrete piers and abutments for the Underwood Bridge, 1948. See figure on next page for more information on the piers. Photo courtesy Lane Memorial Library.

On May 4, 1957 a motorist complained to toll collector Ralph Gove that he "hit an unusual bump" on the Hampton Beach end of the bridge. Gove discovered one of the piers had shifted, dropping a roadway span five inches. The bridge was immediately closed. Cranes were rushed in and timber frames erected under the span to shore it up. The bridge reopened 4 weeks later to traffic under 3-tons.

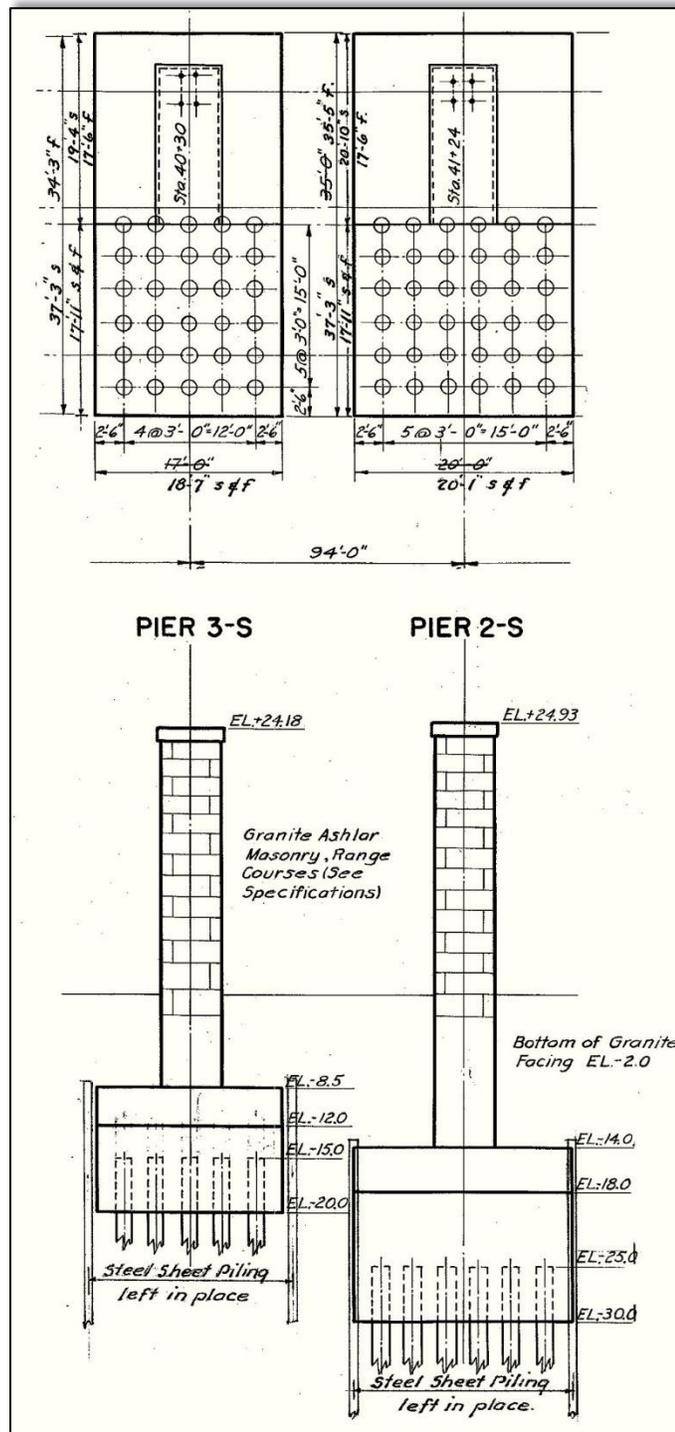
The toll, in place since 1902, was removed by Governor John W. King in a ribbon-cutting ceremony on the bridge October 12, 1964. That left just two toll bridges in the state, Cheshire Bridge over the Connecticut River between Charlestown and Springfield and the Interstate Bridge (Sarah M. Long) over the Piscataqua River between Portsmouth and Kittery.⁷³

The bridge underwent a \$2.5 million rehab in 1985 that included deck and railing replacement, control tower updates and painting. In 2001 a driveshaft in the lifting mechanism broke, leaving the span stuck open for eight hours. The following year the mechanical and electrical systems were repaired and upgraded.

In 2005 the NHDOT set aside \$8 million for repair or replacement of the bridge, preferring a new fixed bridge with greater clearance for boats to eliminate the traffic jams in the summer when the draw is opened. As of this writing (2019) the project to fix or replace the bridge remains on the drawing board as studies, meetings and negotiations are conducted. For more information about the bridge visit the Lane Memorial Library website by scanning the code at right.



Photo 2017, courtesy of Hoyle, Tanner & Associates, Inc.



The massive piers supporting the bridge vary in size. Pier 1 North is larger than those above and carries the trunnion of the draw span, the counterweight and control tower. Pier 1 South is the *rest pier* on which the "light" end of the draw span rests when closed. The piers are anchored with dozens of closely spaced wood pilings, 72 in the case of Pier 2-S. A concrete pile cap roughly 20' x 37' x 10' tall was cast underwater inside steel sheet piling formwork encasing the top 5' of the piles. The pile caps are set 40' below mean low tide in places. Concrete pier shafts faced with granite bear on the pile caps and rise 25' out of the water to carry the deck girder spans.



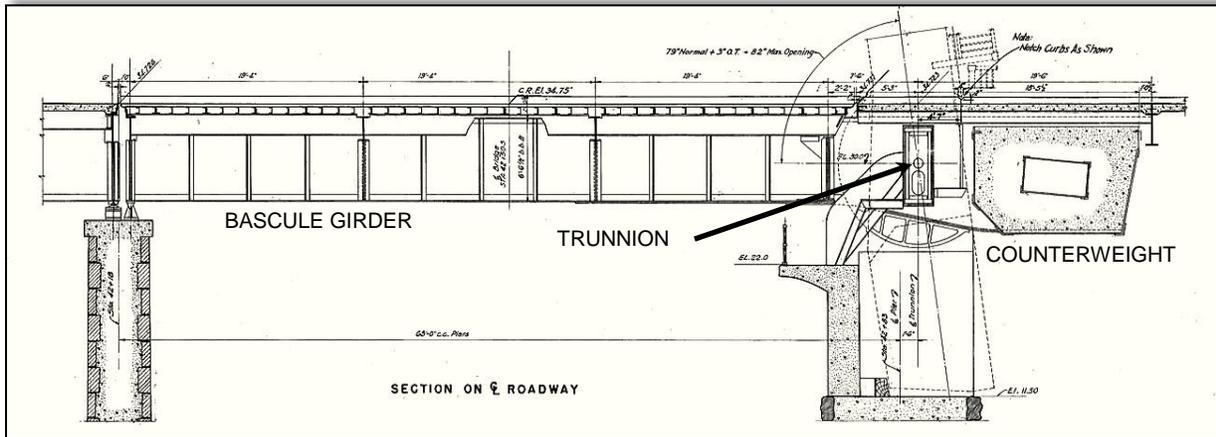
Underwood Bridge completed, 1950, with Mile Long Bridge awaiting demolition. Photo courtesy of Lane Memorial Library.



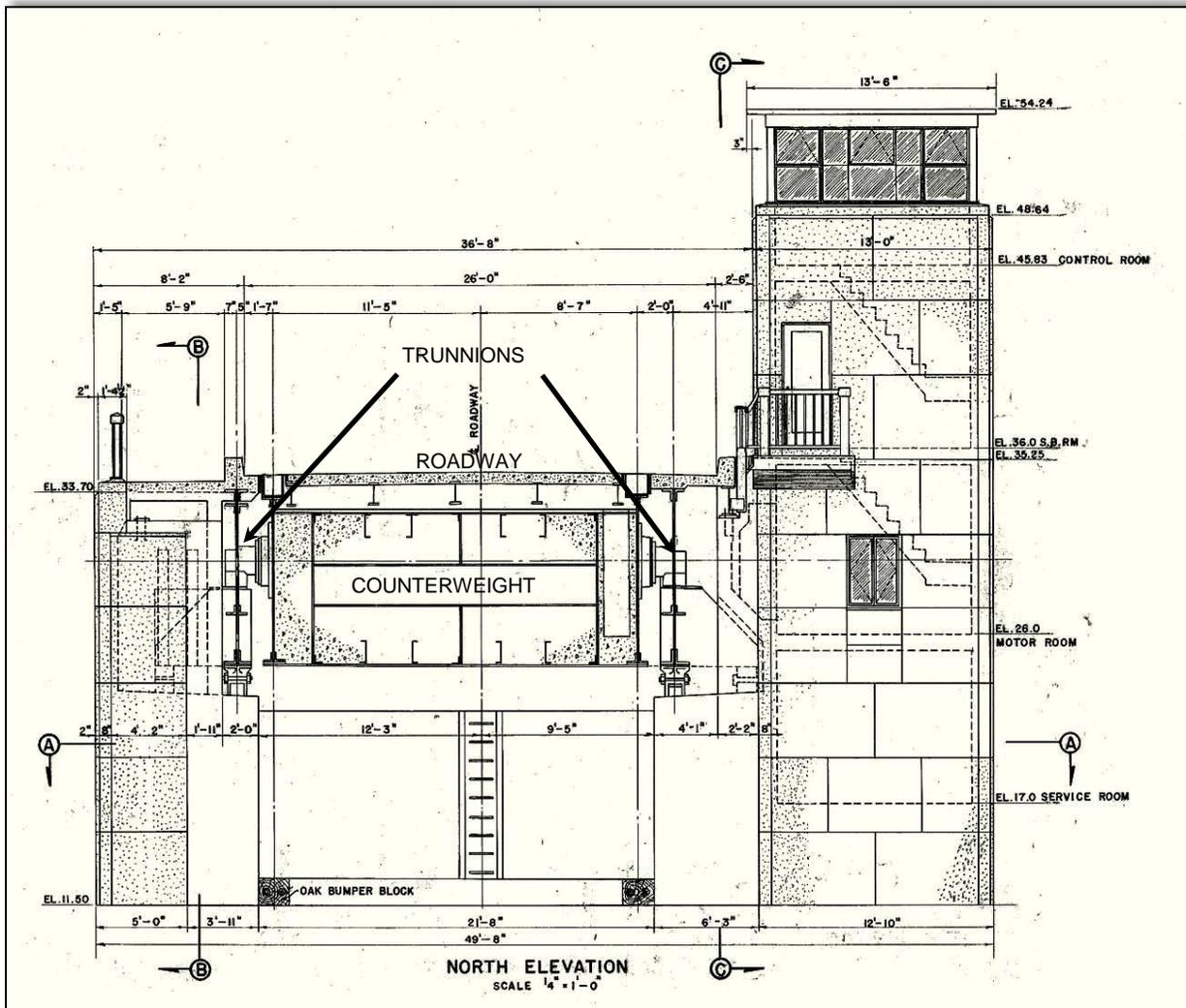
Recently completed bridge with draw span raised, west side, looking northeast, August 31, 1950. Mile Long Bridge remains standing out of view at left, evidenced by shadows. Photo from NH Highway Department bridge inventory card.



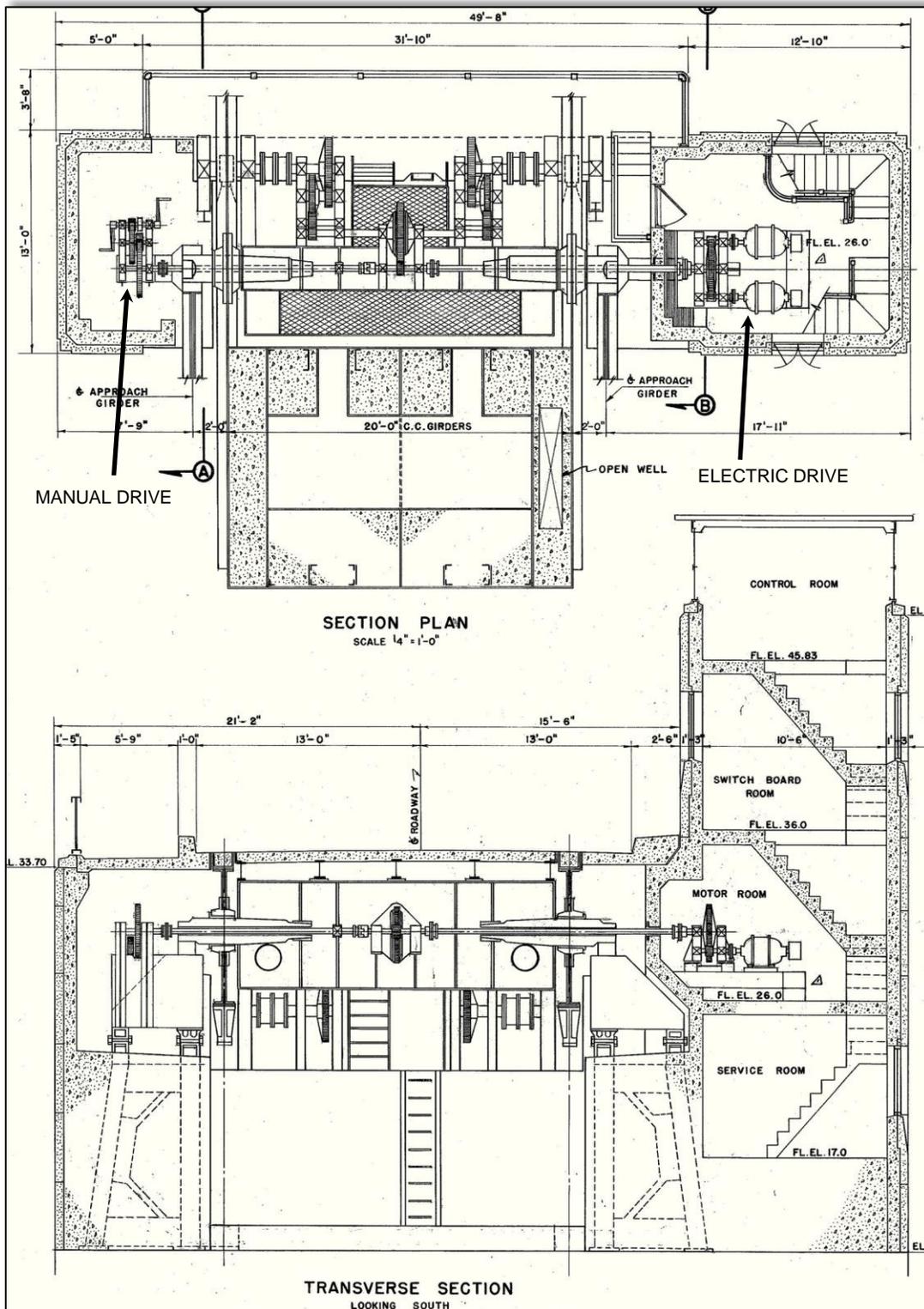
Recently completed bridge, view of deck, control tower and draw in down position, looking north, August 31, 1950. Photo from NH Highway Department bridge inventory card.



Underwood Bridge utilizes a single-leaf, simple-lever (or trunnion) bascule type draw span with an underneath counterweight. The bascule girder pivots ON THE trunnion bearing. The short or tail ends of the bascule girders are connected by cross frames that carry the counterweight, typically a concrete block as in this case.



This end view of the counterweight shows it mounted just below the roadway. The trunnion bearings carry the bascule girders, shown in section, and the counterweight. The bascule girders are riveted plate girders, 6.5' deep and about 86' long overall including the tail girder carrying the counterweight. At right is the north elevation of the control tower.



Operating machinery layout drawings. In the upper drawing at left, is the two-handed, manually-operated "coffee grinder" reduction gearing that turns the drive shaft to open or close the span in the event of a failure of the electric-drive system, powered by two motors at the opposite end of the drive shaft. Lower drawing shows the vertical layout of the control tower, with the control room rising above the highway and electrical/switchboard room, motor room and service room below.

5.0 ENDNOTES

¹ See "Historical Introduction" in Otis Ellis Hovey, *Movable Bridges, Volumes I & II*. New York: John Wiley & Sons, Inc., 1926. Full text online at <https://catalog.hathitrust.org/Record/002018582>

² See David Brooks, "How Long is the Coastline of New Hampshire." *Concord Monitor*, August 16, 2016.

³ New Hampshire Department of Environmental Services (NHDES). *New Hampshire Water Resources Primer*. Concord NH: NHDES, 2008.

⁴ Laws of New Hampshire, 1911, Chapter 21, "An Act to Protect Navigation from Dangerous Obstructions," Approved February 22, 1911.

⁵ *Engineering News*, "Concerning Railway Drawbridges," January 23, 1913: 175.

⁶ "Gibbons v. Ogden." Oyez. Accessed December 11, 2018. <https://www.oyez.org/cases/1789-1850/22us1>.

⁷ Laws of New Hampshire, 1792, Chapter 6, passed June 16, 1792.

⁸ "Navigable waters of the United States are defined as those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. A determination of navigability, once made, applies laterally over the entire surface of the waterbody, and is not extinguished by later actions or events which impede or destroy navigable capacity." (Definition of Navigable Waters of the United States," 33 CFR Part 329.4.); See also, US Army Corps of Engineers New England District. "Navigable Waters of the United States in New England Subject to Section 10, Rivers and Harbors Act Jurisdiction." 2006; Pomeroy, John Norton. *A Treatise on the Law of Water Rights*. St. Paul, Minn.: West Publishing Co., 1893.

⁹ *Engineering News*, "Concerning Railway Drawbridges," January 23, 1913: 175. This editorial followed an article in the same issue, by the C. E. Smith, bridge engineer for the Missouri Pacific Railway, entitled "Drawbridge over Rivers Having Limited Navigation," p. 151.

¹⁰ Montgomery Meigs, "Steamboats and Drawbridges," *Engineering News*, February, 6, 1913, p. 275.

¹¹ See 33 CFR §117.531 Piscataqua River; 33 CFR §117.697 Hampton River; 33 CFR §117.699 Little Harbor.

¹² Access the Coast Guard Bridge Permit Application Guide at <https://www.dco.uscg.mil/Our-Organization/Assistant-Commandant-for-Prevention-Policy-CG-5P/Marine-Transportation-Systems-CG-5PW/Office-of-Bridge-Programs/Bridge-Permit-Application-Process/>

¹³ Merriman Mansfield and Henry S. Jacoby, *A Text-book on Roof and Bridges*. New York: John Wiley & Sons, Inc., 1897.

¹⁴ See Charles C. Schneider, "Movable Bridges," *Transactions of the American Society of Civil Engineers* 40 (1908): 258-336. "C.C." Schneider was one of the first engineers to coin the term "movable bridges" in his seminal 1908 paper on the subject by that name. Schneider was born in Apolda, Germany in 1843. He came to the U.S. in 1867 and quickly rose in the bridge engineering field through a series of jobs with railroads. His cantilever deck truss over the Niagara River, built for the Grand Trunk Railroad in 1883 made him world famous. He was awarded the America Society of Civil Engineers Norman Medal in 1886 for a paper on movable bridges.

¹⁵ Hovey, 1926:17-19. Otis Ellis Hovey (1864-1941) was born in Vermont and graduated first in his class from Dartmouth College in 1889 with the degree of Civil Engineer. He was immediately offered an engineering teaching position at Washington University in St. Louis but left in 1890 for the opportunity to work for the famous bridge engineer George S. Morrison. Morrison was in the prime of his career, winning the best commissions for bridges over the Ohio, Missouri and Mississippi Rivers, and setting bridge building records one after another. Morrison recognized Hovey's exceptional ability and gave him sole responsibility for several large bridge designs normally assigned to engineers twice his age. His principle projects included the approach spans for the Memphis Bridge over the Mississippi, the longest steel truss bridge in the world at the time; the Alton, Illinois Bridge over the Mississippi; the Leavenworth Kansas Bridge over the Missouri; and the superstructure of the Bellefontaine Bridge over the Mississippi at St. Louis.

In 1896 Hovey joined the Union Bridge Company of Athens, Pennsylvania as engineer, where he was in charge of designs and shop and erection drawings for a wide variety of bridges and buildings. In 1900 the Union Bridge Company was bought and merged with other firms to form the American Bridge Company. Hovey was "retained" and offered the position of engineer of design in the Pencoyd, Pennsylvania plant, formerly the Pencoyd Iron Works. This began Hovey's thirty-four year career with American Bridge. In 1907 he was promoted to assistant chief engineer and his office transferred to New York. He held this position until his retirement at age seventy in 1934.

Hovey specialized in movable bridges and turntable mechanisms and during the course of his career designed many of the major structures of that type. The publication of his two volume treatise on movable bridges, still considered the most authoritative work on the subject, and the successful completion of the Santa Fe Mississippi River Bridge, firmly established Hovey as the world's preeminent movable bridge engineer. Hovey was proud of the turning machinery he designed for the bridge and used a photograph of the unit for the frontispiece of his book. Following

retirement from American Bridge he worked as a consulting engineer and lectured regularly at the engineering schools at Princeton, Yale and Dartmouth. He was awarded a Doctor of Engineering from Dartmouth in 1927, and honorary Doctor of Science from Clarkson College of Technology in 1933.

By the end of Hovey's career it is doubtful if there were any professional civil engineers in the U.S. who were not familiar with him. He had managed their money as treasurer of the ASCE from 1921 until his death, but the most vivid memory for most was from the 1940 annual meeting of the Society. Hovey, an accomplished flutist, was joined on stage by concert pianist-turned-engineer Ralph Mojeski on the piano, and John E. Greiner on the Stradivarius violin for a performance of classical music. It was an evening of music which was long remembered "not only for its artistry but for the celebrity of the performers." Hovey was 77 years old, Mojeski 79 and Greiner, 82. Mojeski died a month later, Hovey died the following year, and Greiner the year after that. Sources: American Society of Civil Engineers (ASCE), *A Biographical Dictionary of American Civil Engineers*. New York: ASCE, 1972; ASCE, "Memoir of Otis Ellis Hovey," *ASCE Transactions*, 1943: 1536; "Otis Ellis Hovey," *Civil Engineering*, January, 1938: 56.

¹⁶ J.A.L. Waddell, *Bridge Engineering*. New York: John Wiley and Sons, 1916:701.

¹⁷ In the 1870s, American engineers began to build large iron swing spans of the center-bearing and combined center and rim bearing types for the rapidly expanding railroads. The center-bearing swing was pioneered by Leonardo da Vinci and Salomen de Caux and utilized on all swing spans before the development of the rim-bearing pivot. C. Shaler Smith, a leading nineteenth century bridge engineer, pioneered swing bridge design for several mid-western railroads during the late 1860s and 1870's and published "Draw Spans and Their Turntables (*American Society of Civil Engineers Transactions*, v. 3, 1874), perhaps the earliest technical work on the subject by an American.

¹⁸ Terry L. Koglin, *Movable Bridge Engineering*. Hoboken NJ: John Wiley & Sons, Inc. 2003.

¹⁹ J.A.L. Waddell, *Bridge Engineering*, New York: John Wiley and Sons, 1916:717; "Lift Bridge," U.S. Patent 134,338, December 24, 1872.

²⁰ "Lift Bridge," U.S. Patent No. 506,571, October 10, 1893; J.A.L. Waddell, "The Halsted Street Lift Bridge." *American Society of Civil Engineers Transactions* 33, paper No. 742, January 1895: 1-16.

²¹ Waddell, 1916:723, 744.

²² Egbert R. Hardesty, Henry W. Fischer, and Richard W. Christie, "Fifty-Year History of Movable Bridge Construction—Part 1," *American Society of Civil Engineers Journal of the Construction Division* 101, September 1975: 511-513.

²³ George A. Hool, et. al., *Movable and Long-Span Steel Bridges*, New York: McGraw-Hill Book Company 1943: 159-160.

²⁴ C.P. Hamilton, "Operating Movable Bridges," *Engineering News-Record* 119, November 18, 1937: 827-831; "Special Feature Used in New Lift Span Bridges," *Railway Age* 91, August 1, 1931: 164-168.

²⁵ H. H. Johnson, "Electrically-Operated Movable Railroad and Highway Bridges," *The Electrical Journal* 23, July 1926: 385-389; C.P. Hamilton and G.W. Hewmann, "Controls for Movable Bridges," *Engineering News-Record* 132 (May 4, 1944): 90-96; H.W. Pittenger, "Motors and Controls for Movable Bridges," *Engineering News-Record* (December 19, 1929): 970-973.

²⁶ "Two Heavy Spans Floated into Place to Complete Hackensack River Bridges," *Engineering News-Record* 105 (November 13, 1930): 778; George B. Sowers, "Three Methods for Erecting Lift Bridges," *Engineering News-Record* 125 (August 1, 1940): 62-64.

²⁷ Hovey, 1926: 6, 16, 18.

²⁸ Henry Grattan Tyrell, "Traversing Bridges," *Engineering and Contracting*, June 4, 1913:639.

²⁹ Tom Quinlan and Carl Goldknopf, "Boston Bridge Upgrade," *Modern Steel Construction*, February 1996; New York Landmarks Preservation Commission, "Carroll Street Bridge," Designation List 192, LP-1553, September 29, 1987.

³⁰ Sources for this section include Adams, Nathaniel. *Annals of Portsmouth*. Portsmouth, N.H.: Published by author, 1825; Stoner, J. J. *Bird's Eye View of Portsmouth, New Hampshire, 1877*. Library of Congress digital collection;

³¹ Sources for this section include: James Hill Fitts, *History of Newfields, New Hampshire*. Concord, NH: Rumford Press, 1912; Nancy C. Merrill. *Exeter, New Hampshire, 1888-1988*. Portsmouth, NH: Peter E. Randall Publisher, 1988; Carol Walker Aten, "Exeter is a Seaport," in *Cross-Grained & Wiley Waters: A Guide to the Piscataqua Maritime Region*, Jeffrey W. Bolster, Editor. Portsmouth, NH: Peter Randall Publisher, 2002; *Granite Monthly*, "Down the King's Great Highway: A Sketch of Stratham." March, 1899: 133.

³² Laws of New Hampshire, 1747, Chapter 3, "An Act for Erecting & Maintaining a Bridge over the River at New Market." Passed June 4, 1747.

³³ See Robert A. Whitehouse and Cathleen C. Beaudoin, *Port of Dover, Two Centuries of Shipping on the Cochecho*, Portsmouth: Peter E. Randall, Publisher, 1988; Helen H. Frink, The First Piscataqua River Bridge (The "Great Arch"), 1794—1855." *Historical New Hampshire*, Fall 2013; James L. Garvin, "bridges of the Piscataqua Region," in *Cross-Grained and Wiley Waters*, W. Jeffrey Bolster, Editor, Portsmouth NH: Peter E. Randall Publisher, 2002.; Frank Griggs, Jr. "Piscataqua Bridge." *Structure Magazine*, August 2013; Ruben F. Hull, "Spanning the Bay – Piscataqua Bridge 1794-1855," *New Hampshire Journal of Civil Engineering*, Spring 1996; *Fosters Daily Democrat*, "Recall the

Construction of L.B. Bridge," October, 30, 1933; Donald N. Becker, "Early Movable Bridges of Chicago," *Civil Engineering*, September 1943:421.

³⁴ Laws of New Hampshire 1793, Chapter 15. "An Act to incorporate certain persons for the purpose of building a Bridge over Piscataqua River between Bloody Point and Furbers Ferry, so called and for supporting the same." Approved June 20, 1793.

³⁵ Laws of New Hampshire, 1796, Chapter 13. "An Act to Incorporate the Proprietors of Newhampshire Turnpike Road." Approved June 14, 1796.

³⁶ Sources used for this section include: Eric C. Stoykovich, "Bridge over Troubled Waters: Dover v. The Proprietors of Portsmouth Bridge and the Changing Economic and Legal Landscape, 1815-1845." *Historical New Hampshire*, Fall 2005; Robert A. Whitehouse and Cathleen C. Beaudoin, *Port of Dover, Two Centuries of Shipping on the Cochecho*, Portsmouth: Peter E. Randall, Publisher, 1988; Helen H. Frink, The First Piscataqua River Bridge (The "Great Arch"), 1794—1855." *Historical New Hampshire*, Fall 2013; Laws of New Hampshire 1819, Chapter 49. "An Act to Incorporate the Proprietors of Portsmouth Bridge." Approved June 28, 1819.

³⁷ Laws of New Hampshire, Passed June Session 1841, pp. 585-6.

³⁸ Woodward D. Openo, *The Sarah Mildred Long Bridge*, Portsmouth: Peter E. Randall, Publisher, 1988.

³⁹ Sources in this section include: *Concord Observer*. "New-Castle Bridge," January 21, 1822; *Portsmouth Herald*. "Newcastle Celebrates Today," August 7, 1926; *Lake Village Times*, "The Proprietors of Newcastle Bridge..." December 2, 1876; *Portsmouth Journal of Literature and Politics*: "Stock in Newcastle Bridge," February 4, 1865; "The Ice and Our Bridges," March 20, 1875; "The Proprietors of Newcastle Bridge..." July 22, 1876.

⁴⁰ Laws of New Hampshire, 1821, Chapter 3. "An Act, to incorporate Sundry persons by the name of "The Proprietors of New Castle Bridge, — Approved June 19, 1821."

⁴¹ *Concord Observer*. "New-Castle Bridge." January 21, 1822.

⁴² *New Hampshire Gazette*, "Nearly sixty three years ago..." September 27, 1884. Newspaper clipping in Portsmouth Athenaeum vertical file "Newcastle Bridge."

⁴³ See "New Castle Bridges Now 75% New," *Portsmouth Herald*, n.d.; Wooden Bridge to be Armor Plated, *Portsmouth Herald*, May 7, 1941; "To Close New Castle Bridges for Repairs," *Portsmouth Herald*, December 17, 1940. Newspaper clippings in Portsmouth Athenaeum vertical file "Newcastle Bridge."

⁴⁴ See Walter R. Wheeler, "New Castle-Rye Bridge." NHDHR Inventory Form No. NWC0007. December 11, 2016.

⁴⁵ For the testimony of over twenty witnesses presented in full, see Chapter 3, "The Town of Dover v. The Portsmouth Bridge," in Robert A. Whitehouse and Cathleen C. Beaudoin, *Port of Dover, Two Centuries of Shipping on the Cochecho*, Portsmouth: Peter E. Randall, Publisher, 1988.

⁴⁶ See "Dover v. Portsmouth Bridge & a.," in *New Hampshire Reports: Reports of Cases in the Supreme Court of Judicature in N.H.*, vol 17. Concord, N.H.: McFarland & Jenks, 1864, p. 206. For a summary of the case and its relevance to the development of NH law, see Eric C. Stoykovich, "Bridge over Troubled Waters: Dover v. The Proprietors of Portsmouth Bridge and the Changing Economic and Legal Landscape, 1815-1845." *Historical New Hampshire*, Fall 2005.

⁴⁷ *Portsmouth Herald*, "Railroad to Begin Construction of New Draw bridge at Noble's Island," January 13, 1913; *Portsmouth Herald*, "Electric Machinery for New Draw," August 17, 1918; *Portsmouth Herald*, "Changes Coming on the Boston & Maine," March 12, 1909.

⁴⁸ The first chapter of Woodward D. Openo's *The Sarah Mildred Long Bridge* (Portsmouth: Peter E. Randall, Publisher, 1988) given a detailed history of the Eastern Railroad Bridge and the companion Portsmouth Bridge with numerous photographs by engineer H.D. Peoples.

⁴⁹ Sources in this section include: Portsmouth and Concord Railroad. "Map of the Portsmouth and Concord Railroad, showing its connections with other railroads. November 1845. Prepared by T.J. Carter, Engineer." Digital copy, Library of Congress, Wash. D.C.; *Portsmouth Herald*: "New York Train to Portsmouth," July 134, 1910; B&M May Convert Swing Span Bridge," August 20, 1954; "Concord & Portsmouth Railroad," in *Annual Report of the Railroad Commissioners of the State of New Hampshire*, volume 33. Concord, NH: Edward A. Jenks, state printer, 1877, p. 25.

⁵⁰ Sources in this section include: *Annual Report of the Railroad Commissioners of the State of New Hampshire*, volume 59. Concord, NH: Edward A. Jenks, state printer, 1903; Robert Marston, "Dover, NH People, Businesses and Organizations, 1850 to 1950." Manuscript, Dover Library.

⁵¹ The four other street car lines were the Portsmouth, Kittery & York Street Railway; the Berwick, Eliot & York Street Railway; the Kittery, Eliot & York Street Railway and the Berwick and South Berwick Street Railway. The Atlantic Shore Line Railway was Maine's second largest street railway company.

⁵² Dover Annual Report, 1937, p. 87.

⁵³ Sources utilized include: Langdon B. Parsons, *History of the Town of Rye, New Hampshire*. Concord, NH: Rumford Printing Co., 1905; Walter R. Wheeler, "New Castle-Rye Bridge." NHDHR Inventory Form No. NWC0007. December 11, 2016; *Portsmouth Herald*, "Newcastle Celebrates Today [lifting of tolls]. August 7, 1926.

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- ⁵⁴ Laws of New Hampshire, 1872, Chapter 118 "An Act to authorize construction of a bridge over Little Harbor River in the County of Rockingham, and to give additional power to the County Commissioners." Approved July 3, 1872.
- ⁵⁵ *Chart of coast of New Hampshire, near Portsmouth and the Isles of Shoals*. Library of Congress, Digital Id <http://hdl.loc.gov/loc.gmd/g3744p.ar087400>
- ⁵⁶ Laws of New Hampshire, 1800, Chapter 8. Approved June 14, 1800.
- ⁵⁷ John Albee. *New Castle Historic and Picturesque*. Boston: Rand Avery Supply Co. 1884, p. 33.
- ⁵⁸ Laws of New Hampshire, 1872, Chapter 118. Approved July, 3, 1872.
- ⁵⁹ Peter Randall, *Hampton, a Century of Town and Beach, 1888-1988*. Portsmouth, NH: Published for the town of Hampton, New Hampshire, by P.E. Randall, 1989; John M. Holman, "Hampton's "Mile Long" Wooden Bridge, 1900-1949; The Neil R. Underwood Memorial Bridge, 1949-present." Hampton, NH: Lane Memorial Library 2010. Internet resource: <http://www.hampton.lib.nh.us/hampton/history/publicworks/milelong.htm>;
- ⁶⁰ *Portsmouth Herald*. "New Hampton Bridge Opened." May 15, 1902.
- ⁶¹ "Hampton Bridge Sinking." *Portsmouth Herald*, December 26, 1902.
- ⁶² "Structure Undermined." *Portsmouth Herald*, January 12, 1903, p. 1.
- ⁶³ See the following *Portsmouth Herald* articles: "New Hampton Bridge Opened" May 15, 1902; "Mile Long Structure is Now Undergoing Extensive Repairs." June 18, 1906; "Hampton Harbor Bridge," September 22, 1908; "Big Bridge Badly Battered," March 6, 1911; "Repairs on the Hampton Bridge," September 15, 1917; "Will Rebuild Hampton Bridge," April 5, 1918; "Will Junk The Hampton Line," May 14, 1918; "Hampton Bridge Open to Street Cars," June 21, 1918; "Hampton Bridge is Being Repaired," April 27, 1920.
- ⁶⁴ New Hampshire Laws of 1933, Chapter 159, "An Act Providing for the Acquisition of the Hampton Harbor Toll Bridge and for Emergency Construction for Coastal and Highway Protection."
- ⁶⁵ Additional *Portsmouth Herald* articles include: "Rush Work on Hampton Bridge," August 22, 1934; "Progress on Projects at Hampton," August 29, 1934; "Hampton River Channel Deepens," November 20, 1934; "Hampton Jetty Already Changing Beach Line," March 19, 1935; "New Device for Draw-Lifting on Mile Bridge," October 26, 1936; "Four Lane Bridge to Replace Old Hampton Structure," August 26, 1938.
- ⁶⁶ Documentation on file at New Hampshire Division of Historical Resources, Concord.
- ⁶⁷ Sources in this section include: NHDHR Individual Inventory Form # NWC0007, "New Castle-Rye Bridge." Prepared by Walter R. Wheeler, December 11, 2012. On file at NHDHR, Concord, NH; *Portsmouth Herald*, "Little Harbor Span Under Repairs as Pilings Rot Away, June 15, 1957.
- ⁶⁸ Sources in this section include: John M. Holman, "Hampton's "Mile Long" Wooden Bridge, 1900-1949; The Neil R. Underwood Memorial Bridge, 1949-present." Hampton, NH: Lane Memorial Library 2010. Internet resource: <http://www.hampton.lib.nh.us/hampton/history/publicworks/milelong.htm>; Peter Randall, *Hampton, a Century of Town and Beach, 1888-1988*. Portsmouth, NH: Published for the town of Hampton, New Hampshire, by P.E. Randall, 1989; Homer H. Richardson, "History of the Neil R. Underwood Memorial Bridge," n.d. Manuscript on file at NHDOT. Richardson was a Maintenance Engineer with the NH Dept of Public Works, predecessor to NHDOT; General Electric Company. *Control Apparatus for Hampton Harbor Bridge in New Hampshire. Instruction Manual: Instructions # GEI-27418*. Schenectady, NY: General Electric Company Apparatus Department, n.d. [Located in NH State Archives Box 67091]; United States. War Department. U.S. Engineer Office. Dredging Permit dated July 1, 1941 for Proposed Dredging Hampton Harbor. Application made by New Hampshire Highway Department. [Located in NH State Archives Box 049134; File name: Dredging of Channel (Hampton River)]; Olson, Neil and Chormann, Frederick. *New Hampshire Beaches: Shoreline Movement and Volumetric Change. BOEM/New Hampshire Cooperative Agreement Technical Report (Contract M14ACOOO10)*. Concord, NH: New Hampshire Department of Environmental Services, New Hampshire Geological Survey, January, 2017; *Portsmouth Herald*, "N.H. Commission Recommends Continued Work on Coastline," April 3, 1945.
- ⁶⁹ New Hampshire Laws of 1953, Chapter 72, "An Act Naming the Hampton River Toll Bridge."
- ⁷⁰ Laws of the State of New-Hampshire Passed January Session 1933, Chapter 159. "An Act Providing for the Acquisition of the Hampton Harbor Toll Bridge and for Emergency Construction for Coastal and Highway Protection, Approved April 3, 1933."
- ⁷¹ *Portsmouth Herald*, "Four Lane Bridge to Replace Old Hampton Structure," August 26, 1938; "No Funds For Hampton Bridge Are Available," August 29, 1938; "Two Hampton Project Hearings," February 14, 1941; "Army Studies Hampton Toll Bridge Plans," December 27, 1945.
- ⁷² *Portsmouth Herald*, "Hampton bridge Contract Given." November 27, 1948; "New Hampton bridge Will Open for Business Thurs," December 14, 1949.
- ⁷³ *Portsmouth Herald*, "Free at Last," October 8, 1964; "Free Passage Monday on Underwood Bridge," October 9, 1964; "End of Hampton Bridge Tolls, October 13, 1964.
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